Latin-to-Balinese Script Transliteration Method on Mobile Application: A Comparison

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ABSTRACT

Balinese script writing, as one of Balinese cultural richness, is going to extinct because of its decreasing use. This research is a way to preserve it through collaboration between Computer Science and Language discipline that focused on accuracy comparison of Latin-to-Balinese script transliteration method on mobile application as a ubiquitous learning media. From few research in this area, there are only two existing methods to be compared, i.e. each on Android mobile application that were called Belajar Aksara Bali (BAB), and Transliterasi Aksara Bali (TAB). The comparison was based on The Balinese Alphabet writing rules and examples document by Sudewa. Through the experiment, TAB has outperformed BAB since TAB has passed over 68% (103 of 151) cases, while BAB has passed over only 39% (59 of 151) cases. This research contributes on a comprehensive accuracy comparison analysis of Latin-to-Balinese script transliteration method, specifically on mobile application, since there is no such study. This research also contributes on those methods improvement possibility. In the future, this research can be used as a reference for improvement of any Latin-to-Balinese script transliteration method by taking care on thirteen kind of special words that were found during this comparison study.

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1. INTRODUCTION

The Balinese script, natively known as Aksara Bali or Hanacaraka, is an alphabet used in the Bali Island, Indonesia. It commonly used for writing the Austronesian Balinese language, Old Javanese, and the liturgical language Sanskrit [1]. The script is a descendant of the Brahmi script, and so has many similarities with the modern scripts of South and Southeast Asia. The Balinese script, along with the Javanese script, is considered the most elaborate and ornate among Brahmic scripts of Southeast Asia [2].

Though everyday use of the script has largely been supplanted by the Latin alphabet [3], the Balinese script has significant prevalence in many of the island's traditional ceremonies and is strongly associated with the Hindu religion. The script is mainly used today for copying lontar or palm leaf manuscripts containing religious texts [2].

Based on Indonesia News Agency [3], the less use of the Balinese script has caused concern over the threat of the extinction. As Stern [4] said that saving the language can be done by cultural, political, and economic approach, another approach was taken, i.e. technological approach, by this research that
focused on accuracy comparison of Latin-to-Balinese script transliteration method on mobile application, as it eases people by providing handy transliteration learning by offline on mobile device (no Internet connection needed). Transliteration itself is the conversion of a text from one script to another [5] and is one aspect of Balinese script writing. There are only two existing methods to be compared, i.e. methods on Android mobile application that were called Belajar Aksara Bali (Learning Balinese Script) [6], and Transliterasi Aksara Bali (Balinese Script Transliteration) [7]. These two methods belong to a few detected research in Latin-to-Balinese script transliteration. The comparison was based on The Balinese Alphabet writing rules and examples document by Sudewa [8], as a project script committee related to the proposal by Eversen and Suatjana [1] for encoding the Balinese script in ISO.

Not so many references in this research area. A work related to the same object, i.e. Balinese script, was conducted by Sudana et al. [9] but their work is on Augmented-Reality-based learning media application that was focused on learning on how to write Balinese script. On Latin-to-Balinese script transliteration research area, Sartini et al. [10] has developed a text-to-digital-image converter method. The output is the Balinese script represented by using pre-collected images that were captured from Bali Simbar font [11] display at word processor. Arimbawa et al. [12] has developed a Latin-to-Balinese script transliteration method where the output Balinese script pattern was configured to be written by the robotic system.

2. BALINESE SCRIPT

According to Narendra [13], Balinese script complex behaviours demands complex rendering, includes: 1) Reordering and splitting. Some characters may have more than one separated glyph; 2) Various placement and shape of diacritics based on character context; 3) Contextual shaping which means glyph selection for character is determined by its neighbour character. There are various shape and position of a rendered character located above or below the other character; and 4) Complex ligature construction that was represented by new glyph as a substitution or composition of several glyphs.

Table 1 no. 1–3 shows several Balinese syllables, i.e.: 1) ba (U+1B29 Balinese letter ba); 2) be that comes from ba using pangangge suara e (U+1B3E Balinese sign taling). Pangangge suara is Balinese vowel sign attached to a syllable. According to Simpen [14], taling is placed on the left of the syllable so that it is appeared as if it is written first and then followed by ba. Actually, taling is written later which then change the sound of ba. This case shows Balinese complex behaviour that requires reordering; and 3) bo that comes from ba using pangangge suara o (U+1B40 Balinese vowel sign taling tedung). Separated taling and tedung is written before and after the syllable, respectively. This case shows Balinese script complex behaviour that requires reordering and character splitting. Taling tedung is also an example of a character that has more than one separated glyph.

Table 1 no. 4–7 shows various placement and shape of diacritics based on character context, i.e.: 4) di that comes from da (U+1B24 Balinese letter da) using pangangge suara i (U+1B36 Balinese vowel sign ulu); 5) ding that comes from da using i and pangangge tengenan ng (U+1B02 Balinese sign cecek). Pangangge tengenan is Balinese final consonant. Ulu at di was placed in the middle above character da, while ulu at ding was shifted slightly by cecek; 6) dě that comes from da using pangangge suara è (U+1B42 Balinese vowel sign pepet); and 7) dër that comes from da using è and pangangge tengenan r (U+1B03 Balinese sign surang). Pepet at dě was placed in the middle above character da, while pepet at dër not only was shifted slightly by surang but also become smaller to make width of pepet surang equal to character da below them.

| No | Latin | Balinese | No | Latin | Balinese | Gantungan |
|----|-------|----------|----|-------|----------|-----------|
| 1  | ba    | ꦮ       | 7  | dër   | ꦮ        |           |
| 2  | be    | ꦫ       | 8  | krya  | ꦮ        | (using gantungan ra) |
| 3  | bo    | ꦫ       | 9  | skra  | ꦮ        | (using gantungan ra) |
| 4  | di    | ꦭ       | 10 | krya  | ꦮ        | (using gantungan nya) |
| 5  | ding  | ꦯ       | 11 | na   | ꦮ        |           |
| 6  | dër   | ꦮ       | 12 | ra   | ꦮ        |           |

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Table 1 no. 8–10 show various forms of glyph that represent gantungan of Balinese syllables ra (U+1B2D Balinese letter ra). This gantungan is also called cukra or guwang; 8) kra that comes from ka (U+1B13 Balinese letter ka) using gantungan ra; 9) skra that comes from sa (U+1B32 Balinese letter sa) and ka using gantungan ra; and 10) krya that comes from ka using gantungan rya which is combination of gantungan ra (the third cukra) and gantungan ya (see Table 1 no. 12). The shape of glyph of cukra on kra (the first cukra) is narrower than the shape of glyph of cukra on skra (the second cukra). Besides, glyph is written below ka at the end of the first cukra, while glyph is written beside ka at the end of the second cukra. This case shows the Balinese script complex behaviour that some characters require glyph selection based on character context. Also, the third cukra shows the Balinese script complex behaviour on ligature construction.

Table 1 no. 11–12 show ligatures construction that one example was described above (Table 1 no. 12). Other case, i.e. nā that comes from na (U+1B26 Balinese letter na) that was followed by pangangge suara d (U+1B35 Balinese vowel sign tedung).

3. RESEARCH METHOD

The accuracy comparison of Latin-to-Balinese script transliteration method was conducted on the only two existing methods on mobile application that were called Belajar Aksara Bali [6], and Transliterasi Aksara Bali [7]. The comparison was based on The Balinese Alphabet writing rules and examples document by Sudewa [8], as shown by Table 2. Some of those examples (cases) referred to Simpen [14][15]. Not all of the rules can be tested independently without example, like the appended form of eighteen basic syllables at case 1–18, since provided examples are limited (case 19–25). Table 3 shows provided sentence and its transliteration for the case sixteen (word boundaries and line break rules) at Table 2.

Table 2. Testing cases

| No. | Case     | Remark                                                                 |
|-----|----------|------------------------------------------------------------------------|
| 1   | 1-18     | Table 1 basic syllables (no. 1-18)                                      |
| 2   | 26-34    | Table 2 vowel signs examples: word Kadek (solid) ... Oer (brother)      |
| 3   | 35-44    | Table 3 independent vowel signs (no. 1-10)                              |
| 4   | 52-55    | Table 4 illegal combination of syllable - vowel signs (no. 1-4)        |
| 5   | 58-62    | Table 5 semi vowels examples: word Pak Ramon (Mr. Ramon) ... Braq (laugher) |
| 6   | 63-71    | Table 6 aksara suwalia (no. 1-9)                                       |
| 7   | 79-83    | Table 7 sound killers examples: word Cengceng (a musical instrument) ... Kapal (ship) |
| 8   | 84-85    | Table 8 miscellaneous signs examples: word Mang (a holy letter) ... Sidhoham (perfect) |

Table 3. Provided sentence and its transliteration

| No | Script Example                                                                 |
|----|--------------------------------------------------------------------------------|
| 1  | Latin: Aaah alidara, aah, lahu: alidara suara, 14, alidara wianggane, 33, alidara suara punika taba: dodor pangangge suara, la mahimah suara kakali, saulaliyane suara hilahe suara alidara dvya. (Many letters, 47, i.e., vowels, 14, consonants, 33, those vowels also become vowel signs, and have two type of sounds, each was called sound hilahe and alidara.) |

*refer to table number at Sudewa [8]
4. RESULTS AND ANALYSIS

Experiment for accuracy comparison of Latin-to-Balinese script transliteration method on two existing methods Belajar Aksara Bali version 1.0 [6] and Transliterasi Aksara Bali version 0.0.2 [7] was conducted on Intel(R) Core(TM) i5-6200U CPU @ 2.30GHz platform with 8 GB RAM and Windows 7 64-bit Operating System. For the next reference in this paper, both methods were referred by their abbreviation, i.e. BAB and TAB, respectively. Since both methods were developed by using Android mobile platform, the testing was conducted by using Android Emulator with Nexus 5 platform and Nougat (Android 7.1.1) 32-bit Operating System.

The testing result was shown by Table 4, where column Case represents writing rule or example of Table 2 and column Result shows transliteration result whether correct (check mark) or incorrect (cross mark). Refer to Table 3.

Figure 1 shows sentence transliteration limitations or differences by BAB and TAB, while Figure 2 shows the modified sentence (consists of uncommon words in writing) to get its transliteration result more precise.

Figure 1 shows replacement of character ś, ē, and ĭ by character s, e, and t, respectively, because of limitation on entering such characters on mobile virtual keyboard. Note that TAB provides additional keyboard for character ś. The result analysis was conducted by using Indrawan [16], as references in this research. Table 4 shows the testing results, where TAB has outperformed BAB. TAB has passed over 68% (103 of 151) cases, while BAB has passed over only 39% (59 of 151) cases.

Table 4. Testing results

| Case | Result BAB | Result TAB |
|------|------------|------------|
| 1    | √          | √          |
| 2    | √          | ×          |
| 3    | ×          | √          |
| 4    | √          | ×          |
| 5    | √          | ×          |
| 6    | √          | ×          |
| 7    | ×          | √          |
| 8    | √          | ×          |
| 9    | ×          | √          |
| 10   | √          | ×          |
| 11   | √          | ×          |
| 12   | √          | ×          |
| 13   | √          | ×          |
| 14   | ×          | √          |
| 15   | ×          | √          |
| 16   | ×          | √          |
| 17   | ×          | √          |
| 18   | ×          | √          |
| 19   | ×          | √          |
| 20   | ×          | √          |
| 21   | ×          | √          |
| 22   | ×          | √          |
| 23   | ×          | √          |
| 24   | ×          | √          |
| 25   | ×          | √          |
| 26   | ×          | √          |
| 27   | ×          | √          |
| 28   | ×          | √          |
| 29   | ×          | √          |
| 30   | ×          | √          |
| 31   | ×          | √          |

Note: BAB = Belajar Aksara Bali; TAB = Transliterasi Aksara Bali

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Related to that result, the next sixteen analysis sections has been conducted based on sixteen case types on Table 2, respectively.

4.1. Basic syllables

Eighteen basic syllables (aṅśara vreṣāstra) and provided examples (case on Table 4 no.1–25, or 4.1–4.25) were transliterated correctly by both of BAB and TAB. Each syllable has an appended form (panggange aṅśara) which kill the previous syllable sound. This appended form is called gantungan and gempelan if it hangs below and appearing after the previous syllable, respectively. Not all of this appended form can be tested independently, as described previously at Research Method section.

Case 4.1 need attention related to the more complex transliteration of syllable a, as a counterpart of syllable ha. BAB transliterated independently written syllable a the same as it transliterated independently written syllable ha, while TAB transliterated independently written syllable a the same as it transliterated independently written independent vowel a at case 4.35 (see next section 4.3). Actually, syllable a can be transliterated the same as syllable ha or independent vowel a. It depends on word that has syllable a at the initial position. If that word is a special word, for an example word Aṅśara (letter) at case 4.45 (see next section 4.3), syllable a will be transliterated the same as independent vowel a. Otherwise, that word will be transliterated the same as syllable ha, for an example word Angklung (a musical instrument) at case 4.31 (see next section 4.2). For both BAB and TAB, the transliteration algorithm can be improved to handle those special words through word searching on dictionary (hash table) data structure that according to Cormen et al. [17] will give average time complexity O(1) regardless of the amount of data (words) save inside this kind of data structure. As a note, the use of dictionary data structure was previously done by the authors for biometric data discriminator in [18]–[21]. If certain special word is found there, simply transliterate that word by using independent vowel. Unfortunately, there is still no research to know the precise list of those special words that influence the accuracy of developed transliteration system in general (neither do other special words on the next sections). However, through the implementation of the dictionary data structure, aggregation of known words belong to those special words can be done even the precise list of those special words still not known.

4.2. Vowel signs

Twelve vowel signs, as part of vowels (aṅśara suara), are attached to syllables. They cannot be tested independently, as described previously at Research Method section. Some of provided examples (case 4.26–4.34) were transliterated incorrectly by BAB and/or TAB, i.e. word Kādep (sold), Jēro (house), Angklung (a musical instrument), Daiya (giant), Patūṭ (should be), and Dwī (two) at case 4.26–4.27, 4.31–4.34, respectively.

On case 4.26, word Kādep uses vowel ā as tedong ligature (see next section 4.14) where BAB was failed to transliterate it. Another aspect is that vowel e at reference word Kādep should be written by
using vowel ē (become Kādēp) since vowel sign pepet was used at reference transliteration result (like vowel ē at word Jēro at case 4.27). Both of BAB and TAB were failed to transliterate vowel ē but both of them provide a replacement vowel ē. Actually word Kādēp and its variations (i.e. Kādēp, Kadēp, and Kade) represent another kind of special words since they refer to one meaning and should have same transliteration. The transliteration algorithm improvement on these special words is basically the same as described on special words at previous section 4.1.

On case 4.27, both of BAB and TAB were failed to transliterate vowel ē of word Jēro but both of them provide a replacement vowel ē, as described previously at word Kādēp. Actually word Jēro and its variation (i.e. Jer) represent same kind of special words like previous word Kādēp since they refer to one meaning and should have same transliteration. Another aspect on TAB is that tedong ligature (see next section 4.14) should not be constructed on vowel o of word Jēro since it was not pronounced longer like vowel ā (that construct ligature) of word Kādēp. It seems that TAB constructs tedong ligature automatically if glyph tedung is found after regular form ra and no checking that glyph tedung and glyph taling precede that regular form ra actually construct ro not rō. This limitation must be taken care of for the algorithm improvement of TAB.

On case 4.31, vowel A of word Angkling was failed to be transliterated by both of BAB and TAB because of improper algorithm handling of uppercase vowel and incorrect usage of indepened vowel, respectively. On case 4.32, both of BAB and TAB were failed to transliterate vowel sign taleng repa ai of word Daitya but TAB provide a replacement vowel ė. It related to diphthong ai that is pronounced as long vowel ē. Actually word Daitya and its variation (i.e. Dētya) represent another kind of special words since they refer to one meaning and should have same transliteration. The transliteration algorithm improvement on these special words is basically as described on special words at previous section 4.1. On case 4.33, both of BAB and TAB were failed to transliterate vowel sign suku ilut ū of word Pātī as BAB. On case 4.33, TAB was failed to transliterate vowel sign ulu sari ė of word Dwī. Actually word Pātī and its variation (i.e. Patut); and word Dwī and its variation (i.e. Dwi) represent same kind of special words like previous word Kādēp since each refer to one meaning and should have same transliteration.

4.3. Independent vowels

Ten independent vowels, as part of vowels (akṣara suara), are used at initial position of the word (case 4.35–4.51). Some of them and their provided examples were transliterated incorrectly by BAB and/or TAB, i.e. vowel ā, ī, ū, word Akṣara (letter), Iswara (God’s name), Upacāra (ceremony), Eka (one), Airlangga (a Javanese king), Ong (a holy letter), and Om (symbol of God) at case 4.36, 4.38, 4.40, 4.42, and 4.45–4.51, respectively.

On case 4.35, 4.37, 4.39, and 4.41–4.43, independently written vowel a, i, u, e, ai, and au can be transliterated by using syllable ha with its vowel sign (BAB approach), or by using independent vowel (TAB approach). On case 4.36, 4.38, and 4.40, vowel ā, ī, and ū (using tedong ligature, see next section 4.14) was failed to be transliterated by BAB. BAB was failed to transliterate vowel ā but it provides a replacement vowel ū (see previous section 4.2). On case 4.42, independently written vowel airsania ai should be mapped to vowel ē for correct transliteration. Case 4.44 is basically the same as case 4.42 but on different independently written vowel au that should be mapped to vowel ō for correct transliteration by BAB (related to the diphthong au that is pronounced as the long vowels ō).

On case 4.49, word Airlangga also was failed to be transliterated by both of BAB and TAB because of improper algorithm handling of uppercase vowel and no surang was used for consonant r, respectively. On case 4.45, one aspect of word Akṣara has already been analysed (see previous section 4.1). Another aspect is that consonant ś of word Akṣara was failed to be transliterated by both of BAB and TAB but only TAB provides a replacement consonant s (related to syllable sa sapa, see next section 4.6) to give correct transliteration. On case 4.46, word Iswara was failed to be transliterated by both of BAB and TAB. On BAB, lowercase vowel must be used to give correct transliteration result. On TAB, a replacement consonant ś was provided for consonant s (related to syllable sa sapa, see next section 4.6).

On case 4.47, word Upacāra was failed to be transliterated by BAB. Lowercase vowel must be used to give correct transliteration result. Actually word Upacāra and its variation (i.e. Upacara) represent same kind of special words like previous word Kādēp since they refer to one meaning and should have same transliteration. On case 4.48, word Eka was failed to be transliterated by BAB except by using lowercase vowel. On case 4.50, word Ong was transliterated incorrectly by both of BAB and TAB. It was constructed not only by independent vowel o kara O but also by using sound killer ulu candra (see next section 4.8), instead of cecak (see next section 4.7), to end inherent sound of syllable nga. On case 4.51, word Om was transliterated incorrectly by both of BAB and TAB.
not only by independent vowel o kara tedung Ô but also by using sound killer ulu candra (see next section 4.8 and 4.9), instead of adeg-adeg (see next section 4.7), to end the inherent sound of syllable ma.

4.4. Syllable - vowel sign combination

Illegal combination of syllable - vowel signs happened on case where all of basic syllables (see previous section 4.1) can have any of vowel signs (see previous section 4.2), except ra and la that cannot have è or ā appended to them. They must use regular form ra repa and la lenga, respectively (case 4.52–4.57). All of the cases were transliterated incorrectly by both of BAB and TAB, i.e. ré, lé, lâ, word Talêr (also), and Kêrêng (eat a lot). Common cause is a limitation on entering vowel è on mobile application. However, both of BAB and TAB provide a replacement vowel è. Next analysis was based on this replacement vowel è.

On case 4.56 by TAB, syllable lé of word Talêr was transliterated incorrectly by using illegal combination of syllable la and vowel sign pepet (to kill previous sound a of la and replace it with sound è), instead of using regular form la lenga. If word was written without r, lé was transliterated correctly. All of this inconsistency need to be taken care of for algorithm improvement. On case 4.57 by both BAB and TAB, syllable ré of word Kêrêng was transliterated incorrectly by using illegal combination of syllable ra and vowel sign pepet (to kill previous sound a of ra and replace it with sound è), instead of using regular form ra repa. On both BAB and TAB, if word was written without ng, ré was transliterated correctly. All of this inconsistency need to be taken care of for algorithm improvement. Actually word Talêr and its variation (i.e. Taler); and word Kêrêng and its variation (i.e. Kerêng) represent another kind of special words since each refer to one meaning and should have same transliteration. The transliteration algorithm improvement on these special words is basically the same as described on special words at previous section 4.1.

4.5. Semi vowels

Four semi-vowels (ardu suara) attached to syllable, i.e. guwung, suku kembung, gantungan la, and nania for ra, wa (u), la, and ya (ia), respectively. From all of provided examples (case 4.58–4.62), only case 4.62 was transliterated incorrectly by both of BAB and TAB, i.e. word Briag (laughter).

On case 4.62, word Briag should be transliterated by stacking together cakra and nania. On TAB, using ya (rather than ia) at word Briag gave correct transliteration result. Actually word Briag and its variation (i.e. Bryag) represent another kind of special words since they refer to one meaning and should have same transliteration. The transliteration algorithm improvement on these special words is basically the same as described on special words at previous section 4.1. On case 4.58 and 4.59, word Pak Raman and Pakraman were transliterated differently by BAB, and were transliterated the same by TAB. Both of transliteration approach are correct. On BAB, ra of word Pak Raman was transliterated by using semi-vowel cakra, while syllable ra of word Pakraman was transliterated by using basic syllable ra and preceded by sound killer adeg-adeg to form consonant k of word Pakraman (see next section 4.7). On TAB, both of those words were transliterated by using mechanism on word Pak Raman by BAB.

4.6. Akṣara śwalalita

Nine akṣara śwalalita, in addition to the eighteen basic syllables (see previous section 4.1), are used for writing Kawi (Old Javanese) word. All of these syllables and their provided examples were transliterated incorrectly by BAB. Some of them and their provided examples were transliterated incorrectly by TAB, i.e. ŋa, ŏ (syllable ta tawa), ša (syllable sa saga), sa (syllable sa sapa), word Gaṇitṛi (chain), Partha (man’s name), Jaṭayu (a bird), Bhiśama (decree), and Śiwa (God’s name) at case 4.63, 4.66–68, 4.72, and 4.74–4.77, respectively.

On case 4.63, and 4.66–68 by TAB, replacement syllables were provided, i.e. ŋa, ŏ (syllable ta tawa), ša (syllable sa saga), and sa (syllable sa sapa), respectively. The usage of those replacement syllables solve all of illegally transliterated words related to ākṣara śwalalita. Actually, word Gaṇitṛi and its variation (i.e. Gaṇitṛi); Jaṭayu and its variation (i.e. Jaṭayu); Bhiśama and its variation (i.e. Bhiśama); and Śiwa and its variation (i.e. Śiwa) they represent another kind of special words since each refer to one meaning and should have same transliteration. The transliteration algorithm improvement on these special words is basically the same as described on special words at previous section 4.1.

4.7. Sound killers

Four sound killers (pangangge tengenan), i.e. ccek, surang, bisah, and adeg-adeg, are used to end sound of a syllable and represent consonant ng, r, h, and others, respectively. Adeg-adeg is the default sound killer that appears after a syllable (other than syllable nga, ra, and ha). Their appended form of
these syllables cannot be tested independently, as described previously at Research Method section. Some of provided examples (case 4.79–4.83) were transliterated incorrectly by BAB and/or TAB, i.e. word Cengceng (a musical instrument) and Karṇa (ear) at case 4.79 and 4.82, respectively.

On case 4.79 by BAB, cecek should be constructed in the middle of word because word Cengceng has same vowels. On case 4.82 by TAB, there is no surang was used for consonant r, the same as word Airlangga (a Javanese king) at case 4.49 (see previous section 4.3), Talérv (also) at case 4.56 (see previous section 4.4) and Table 3, Partha (man’s name) at case 4.73 (see previous section 4.5), and dirgha (long sound vowels) at Table 3. Inconsistency was shown since surang was only used for consonant r at the end of the word Talérv even though it can appear anywhere. This limitation must be taken care of for the algorithm improvement.

4.8. Miscellaneous signs
Two miscellaneous signs (part of aksāra modre), i.e. ulu candra and ulu ricem, are kind of sound killers (see previous section 4.7) that are used to write Sanskrit words, usually part of prayers. They are used to end the sound of a syllable and represent consonant ng and m, respectively (at previous section 4.7, their counterpart sound killer of ng and m is cecek and adeg-adeq, respectively). All of provided examples were transliterated incorrectly by both of BAB and TAB, i.e. word Mang (a holly letter) and Siddham (perfect) at case 4.84 and 4.85.

On case 4.84 by TAB, a replacement consonant ṃ was provided for consonant cluster ng of word Mang. On this case, word Mang represent another kind of special words that there is still no research to know the precise list of them. The transliteration algorithm improvement on these special words is basically the same as described on special words at previous section 4.1. On case 4.85 by TAB, a replacement consonant ś and m were provided each for consonant ś and m of word Siddham. On this case, word Siddham represent another kind of special words that there is still no research to know the precise list of them. The transliteration algorithm improvement on these special words is basically the same as described on special words at previous section 4.1.

4.9. Holy symbol
When independent vowel au kara (see previous section 4.3) met sound killer ulu candra (see previous section 4.8), the Romanization is not Aung, but Om. Om has a special name, i.e. Ongkara, as a holy symbol (aksāra modre). The most notable sentences using Om are the greetings. All of provided examples (case 4.86–4.87) were transliterated incorrectly by both BAB and TAB, i.e. phrase Om Svastiastu (May God blesses you) and Om Šanti, Šanti, Šanti, Om (May peace be everywhere) at case 4.86 and 4.87, respectively.

On case 4.86 by TAB, a replacement independent vowel o kara tedung Ō for vowel O and replacement consonant ṃ for consonant m of word Om was provided. Om represent another kind of special words and the transliteration algorithm improvement on these special words is basically the same as described on special words at previous section 4.1. Word Svastiastu should be transliterated by stacking together cakra and nania (see previous section 4.5). By using ya (rather than ia) at this word, it gave correct transliteration result. Actually, word Svastiastu and its variation (i.e. Swastyastu) refer to one meaning and should have same transliteration. On this case, they represent same kind of special words like word Briag (laughter) at case 4.62 (see previous section 4.5). On case 4.87 by TAB, a replacement consonant, i.e. consonant ś, was provided for consonant Š of Šanti (related to syllable sa saga, see previous section 4.6).

4.10. Miscellaneous syllables
The existence of two miscellaneous syllables (that apparently borrowed from Javanese) in Balinese script is very rare (case 4.88–4.89). On case 4.88, syllable cha was transliterated incorrectly by both BAB and TAB. Syllable cha has no regular form. It is always paired with the normal form of syllable ca. On case 4.89, syllable kha was transliterated incorrectly only by BAB.

4.11. Digits
All of the digits (0–9) were transliterated correctly by BAB and TAB (case 4.90–4.99).

4.12. Punctuations
All of independently written punctuations (case 4.100–4.107) were transliterated incorrectly by BAB. By TAB, comma (,), period (.), less-than (<), period-0-period (.0.), greater-than (>), double greater-than (>>), and colon (:) sign was transliterated correctly become carik (case 4.100), carik pareren (case
4.13. Some variation of usages

Some variation of usages includes: 1) Incorrect combination of independence vowel a kara (see previous section 4.3) and vowel signs (see previous section 4.2); 2) Special use of syllable pa kapal (see previous section 4.6) that is never attached to suki or suku ilut (see previous section 4.2); 3) Romanization of the inherent sound; and 4) The use of pangan ge aksha (see previous section 4.1).

On first variation of usages, for any vowel sounds, there are independent vowel glyphs that are ready to be used. On case 4.108–4.111, incorrect combination of independence vowel a kara and vowel sign were shown by using a kara combined with ulu, suku, taling, and taling-te dung. None of those incorrect combination came up on BAB and TAB. On case 4.112–4.113, vowel sound ę and ō that don’t have independent vowel form, should be written by using syllable ha combined with pepet and pepet-te dung at case 4.112 and 4.113, respectively. Vowel sound ę and ō were transliterated incorrectly by both of BAB and TAB.

On second variation of usages, pa kapal can be paired with any vowel signs but its shape is not the same as other syllables since its final stroke is not going down. Hence suki and suku ilut cannot be attached to pa kapal but they are can positioned below it. On case 5.114, syllable pa that was paired with suku, was transliterated correctly by BAB and TAB. On case 5.115, pa kapal that was paired with suku, was transliterated correctly only by TAB.

On third variation of usages, a stand-alone syllable has inherent sound that is always Romanized as a and it is common to a Balinese to pronounced an a at the end of a word as ē. On case 5.116, word sekale’ (real) was transliterated incorrectly by BAB and TAB since there is transliteration difference with word sekala. For both of word, vowel e at reference word sekala should be written using vowel ē (become sekala) since pepet was used at reference transliteration result. Actually, word Sekala and its variations (i.e. Sekalé, Sıkala, and Sekalé) represent another kind of special word since they refer to one meaning and should have same transliteration. The transliteration algorithm improvement on these special words is basically the same as described on special words at previous section 4.1.

On fourth variation of usages, several provided examples of case 4.117–4.124 were transliterated incorrectly by BAB and/or TAB, i.e. word Sukšma (thank you), Ksatria (warrior), Stri (wife), Smerti (books of Veda), Utama (primary), and Dharma (religion) at case 4.118–4.123, respectively. First four examples are called pluta which are very rare form of gantungan or gempelan, when a non semi-vowel acts like a semi vowel (see previous section 4.5). Last two examples are called dwita that have double consonant syllable, but actually a single sound.

On case 4.117, consonant m of word Samping (side) was transliterated correctly by both of BAB and TAB without using adeg-adeq in the middle of word. On case 4.118, consonant k of word Sukšma was transliterated correctly by both of BAB and TAB without using adeg-adeq in the middle of word, but its consonant ś was failed to be transliterated by both of them. On case 4.119, consonant ś of word Ksatria was transliterated incorrectly by both of BAB and TAB. This case is the same as word Sukšma at case 4.118. Another aspect on BAB, vowel cluster ia need to be written iya for correct transliteration. This is the case where vowel cluster ia was not transliterated by using vowel sign (see previous section 4.2) or by changing it first become ya (see next section 4.5). Actually, word Ksatria and its variations (i.e. Ksatria, Ksatriya, and Ksatriya) represent another kind of special words since they refer to one meaning and should have same transliteration. The transliteration algorithm improvement on these special words is basically the same as described on special words at previous section 4.1. On case 4.120, vowel sign ulu sari i of word Stri was transliterated incorrectly by BAB. On case 4.121, vowel e at reference word Smerti should be written by using vowel ē (become Smerti) since gantungan mê was used at reference transliteration result. This gantungan mê of word Smerti was transliterated incorrectly by both of BAB and TAB, even both of them provide a replacement vowel ō for vowel ē. On case 4.122, word Utama was transliterated incorrectly by both of BAB and TAB. On TAB, it need to be written as Uthama for correct transliteration. On case 4.123, word Dharma was transliterated incorrectly by both of BAB and TAB. On TAB, it need to be written Dharmma for correct transliteration. Actually, word Utama and its variation (i.e. Uthama) and word Dharma and its variation (i.e. Dharmma) represent another kind of special words since each refer to one meaning and should have same transliteration. The transliteration algorithm improvement on these special words is basically the same as described on special words at previous section 4.1.
4.14. Ligatures

Ligature as one pen strokes of two glyphs is desirable but not mandatory form. Tedung form ligatures with certain syllables. Suku and suku ilut form ligatures with certain gantungan or gempelian (see previous section 4.1). On case 4.125–4.146, tedung ligatures were transliterated incorrectly by BAB.

4.15. Abbreviations

Three different scheme for abbreviations can be used in Balinese, i.e.: 1) The one endorsed by the government to abbreviate government institutions. The scheme is to follow the way the abbreviation pronounced in Indonesian language; 2) The one used by [15]. The scheme is to use the first syllable with all the vowel signs attached to it; or if it is an independent vowel, then the independent vowel itself is used; and 3) The one less commonly used, but somehow the shortest one. The scheme is to use only syllable or independent vowel.

On case 4.147–5.150, phrase Bank Pembangunan Daerah Bali (Development Bank of Bali Province) and all of its three abbreviation schemes were transliterated incorrectly by both BAB and TAB. Latin abbreviation of that phrase is BPD Bali and its three abbreviation schemes, i.e Be Pe De Bali, Ba Pe Da Bali, and Ba Pa Da Bali at case 4.148–4.150, respectively. On all of abbreviations schema there are cariks (see previous section 4.12) between syllable and/or word that still cannot be accommodated by BAB and TAB since there is no way to differentiate between this abbreviation phrase with non-abbreviation phrase. On case 4.147, word Bank need to be written as Bang for correct transliteration. Since consonant ng has the same pronunciation with consonant nk (foreign sound), it was used for transliteration. On this case, word Bank represent another kind of special words and the transliteration algorithm improvement on these special words is basically the same as described on special words at previous section 4.1.

4.16. Word boundaries and line break rules

There are no spaces to separate words in Balinese script. In the old time of writing on dried palm leaves (it was called lontar), spaces were scarce and the “page setup” for lontar was always a thin landscape. The number of lines is small, with every space must be filled for optimal use. There was common practice to break the sentence at any places. On case 4.151, several words of sentence were transliterated incorrectly by BAB and/or TAB, i.e. Akeh (Many), luir (i.e.), ipun (a pronoun to previous word aksara), suara (vowel), wianjana (consonant), madrêve (have), kawâşţanin (called), hrêswa (short vowel), and dirgha (long vowel).

On word Akeh by BAB and TAB, vowel A was failed to be transliterated because of improper algorithm handling of uppercase vowel and incorrect usage of independent vowel (see previous section 4.1), respectively. On BAB, using lowercase vowel gave correct transliteration result, the same case on word Angklung (a musical instrument) at case 4.31 (see previous section 4.2).

Figure 2 shows how word Akeh was simply modified become Hakeh, which is uncommon in writing but right in transliteration. On word luir by BAB and TAB, semi vowel ua (that construct ui by using vowel sign iulu) was transliterated incorrectly except it was written as wa (see previous section 4.5), as show by

Figure 2. On word ipun by TAB, vowel i was transliterated incorrectly because of incorrect usage of independent vowel (see previous section 4.1).

Figure 2 shows how word ipun were simply modified become hipun, which is uncommon in writing but right in transliteration. On word suara by TAB, semi vowel ua was transliterated incorrectly except it was written as wa (see previous section 4.5), as shown by

Figure 2. On word wianjana by TAB, semi vowel ia was transliterated incorrectly except it was written as ya (see previous section 4.5), as shown by

Figure 2. At another aspect, cluster nj was transliterated incorrectly by using gantungan ja on syllable na, instead on syllable nga. This is because there is assimilation combination on syllable na into syllable nga [22]. TAB provide replacement consonant ň for consonant n of cluster nj for correct transliteration. Actually, word wianjana and its variations (i.e. wianjana, wiañjana, and wyanjana) represent another kind of special words since they refer to one meaning and should have same transliteration. The transliteration algorithm improvement on these special words is basically the same as described on special words at previous section 4.1.

On word madrêve by BAB and TAB, vowel ê was failed to be transliterated but both of them provide a replacement vowel é. On word kawâšţanin, consonant cluster št were transliterated incorrectly by both of BAB and TAB. On BAB, vowel ď was also transliterated incorrectly. Replacing consonant cluster št by using consonant cluster st gave correct transliteration at that part of word. On TAB, replacing
consonant cluster $\text{ṣ}b$ by using consonant cluster $\text{ṣ}f$ (related to syllable $\text{sa sapa}$ and $\text{ta twa}$, see previous section 4.6) gave correct transliteration result. On word $\text{hrēswa}$ by BAB and TAB, vowel $\acute{e}$ was failed to be transliterated but both of them provides a replacement vowel $\acute{e}$. On word $\text{dirgha}$, vowel $\acute{i}$ and $\acute{a}$ (related to vowel sign $\text{ulu sari}$ and syllable $\text{ga gora}$, see next section 4.2 and 4.6, respectively) were failed to be transliterated by BAB but if written as word $\text{dirga}$, it gave correct transliteration result. On TAB, there is no surang was used for consonant $r$ (see previous section 4.2).

5. CONCLUSION

Comprehensive accuracy comparison of Latin-to-Balinese script transliteration method on two existing methods on Android mobile application. i.e. Belajar Aksara Bali (BAB), and Transliterasi Aksara Bali (TAB) has already been conducted. Through the experiment, TAB has outperformed BAB where TAB has passed over 68% (103 of 151) cases, while BAB has passed over only 39% (59 of 151) cases. Cases based on The Balinese Alphabet writing rules and examples document by Sudewa [8], as a project script committee related to the proposal by Eversen and Suatjana [1] for encoding the Balinese script in ISO.

Accuracy of Latin-to-Balinese script transliteration method can be improved significantly by taking care of thirteen kind of special words that was identified on the testing cases during the experiment. These kind of special words, i.e.: 1) The word where its vowel at the initial position was specifically transliterated by using the independent vowel. For an example: $\text{Aksara}$ (letter); 2) Group of words where different writing of long vowel ($\ddot{a}$, $\ddot{i}$, $\ddot{u}$, or $\ddot{o}$) refer to one meaning and should be transliterated the same. For an example: $\text{Kadēp}$ (sold) – $\text{Kadēp}$ (sold); 3) Group of words where different writing of vowel $\acute{e}$ refer to one meaning and should be transliterated the same. For an example: $\text{Jero}$ (house) – $\text{Jero}$ (house); 4) Group of words where their vowels belong to a pair of diphthong: $\acute{a}$ – $\acute{e}$ or $\acute{a}$ – $\ddot{o}$ should be transliterated the same. For an example: $\text{Daiya}$ (giant) – $\text{Dētya}$ (giant); 5) Group of words where different writing of $\text{ra repa}$ (ré or rō) or $\text{la lenga}$ (lē or lō) refer to one meaning and should be transliterated the same. For an example: $\text{Talēr}$ (also) – $\text{Taler}$ (also); 6) Group of words where different writing of semi-vowels ($\text{ra}$, $\text{re}$, $\text{rō}$, $\text{ua}$, $\text{la}$, or $\text{ia}$) refer to one meaning and should be transliterated the same. For an example: $\text{Briag}$ (laughter) – $\text{Bryag}$ (laughter); 7) Group of words where different writing of $\text{aksara}$ $\text{svalalita}$ ($\text{ña}$, $\text{dha}$, $\text{tha}$, $\text{ṭa}$, $\text{ṣa}$, $\text{śa}$, $\text{gha}$, $\text{bha}$, or $\text{pha}$) refer to one meaning and should be transliterated the same. For an example: $\text{Bhisama}$ (decree) – $\text{Bhīsama}$ (decree); 8) The word where its syllable sound must be end by using miscellaneous signs (ulu candra or ulu ricem) as part of $\text{aksara}$ $\text{modre}$ sign (holy symbol). For an example: $\text{Om}$ (a holy letter); 9) The word where its vowel $\acute{a}$ at the end position can be pronounced (and written) as vowel $\acute{e}$ (creating a counterpart word). This group of words should be transliterated the same. For an example: $\text{Sēkāla}$ (real) – $\text{Sēkalē}$ (real); 10) The word where its vowel combination $\text{ia}$ can be written as the vowel-consonant combination $\text{iya}$ (creating a counterpart word). This group of words should be transliterated the same. For an example: $\text{Kśatriya}$ (warrior) – $\text{Kśatriya}$ (warrior); 11) The word where its single consonant syllable and the word where its double consonant syllable actually each has a single same sound ($\text{dvita}$) for those syllables. This pair of words should be transliterated the same. For an example: $\text{Utama}$ (primary) – $\text{Utama}$ (primary); 12) Foreign word. For an example: $\text{Bank}$; and 13) Group of words where different writing of assimilation combination on syllable $\text{na}$ into syllable $\text{nga}$ refer to one meaning and should be transliterated the same. For an example: $\text{wianjana}$ (consonant) – $\text{wyanjana}$ (consonant).

In general, this research contributes on a comprehensive accuracy comparison analysis of Latin-to-Balinese script transliteration method since there is no such study before in this research area. In specific, this research contributes on identification of Latin-to-Balinese script transliteration methods on mobile application (as ubiquitous learning media) and determine their accuracy and improvement possibility. In a future, this research can be used as a reference for improvement of any Latin-to-Balinese script transliteration method that can be made by taking care on thirteen kind of special words that were found during this comparison study.

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