An Improved Algorithm and Accuracy Analysis Testing Cases of Latin-to-Balinese Script Transliteration Method based on Bali Simbar Dwijendra Font

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Abstract

As part of the Balinese culture, the Balinese script has rarely been used today. Its Latin-to-Balinese script transliteration knowledge is also affected by that condition. This study aims to preserve that knowledge through technological approaches. By collaboration between informatics and linguistics discipline, this research improves the Latin-to-Balinese script transliteration method from the previous research. This method can be used as a core for the web/mobile-based transliteration learning application. The improvements that were taken in this research are: 1) the utilization of Bali Simbar Dwijendra font rather than the previous Bali Simbar-B font; and 2) additional accuracy analysis testing cases to the previous accuracy analysis testing cases from The Balinese Alphabet writing rules and examples document. As main contribution in this research area, this method was considered as the first Latin-to-Balinese script transliteration method that utilizing Bali Simbar Dwijendra font. This font is the enhancement from the previous Bali Simbar-B font related to its size which are bigger and thicker for better visual at the same font size. With certain keyboard layout application, it also makes easier and more natural to type it in programs and across the web. Additional 47 testing cases to the previous 151 testing cases related to the sound killers (gantungan) that has no example at The Balinese Alphabet writing rules and examples document. Those examples were taken from another credible source, i.e. the Balinese script dictionary from the Bali Province government. Through the experiment, this method has accuracy up to 98% (195 of 198) testing cases that has passed through all additional 47 cases, and 148 cases from the previous 151 cases. Related to the previous 151 cases, this improved method maintained same accuracy rate to the previous method. Execution time for relatively more complex sentence case type gave relatively real time result at 10.99ms on average on certain hardware and Operating System platform. In the future work, this method accuracy could be improved significantly by: 1) enriching the repository consists of words belong to special words from the Balinese script dictionary; and 2) implementing semantic relation transliteration.

I. INTRODUCTION

The decreasing use of Balinese script, including its Latin-to-Balinese script transliteration knowledge, has caused concern over the threat of the extinction. Preservation effort by the government has already been conducted through Bali Governor Circular Letter No. 3172/2019 that follows up Bali Governor Regulation No. 80/2018 [1][2][3]. Each of them is about recommendation the Balinese Script usage on

national and international event hosted in Bali, and about regulation of protection and usage of Balinese Language, Script, and Literature, and organizing the Balinese Language Month.

As preservation effort of the language can be done by previous political approach, another approach, i.e. technological approach, was taken by this research through the improvement of Latin-to-Balinese script transliteration method from the previous research [4]. All of these methods can be used as a core for the web/mobile-based transliteration learning application [5][6][7][8]. The improvements that were taken in this research are: 1) the utilization of Bali Simbar Dwijendra (Bali Simbar DJ) font [9] rather than the previous Bali Simbar-B font [10][11]; and 2) additional accuracy analysis testing cases from the Balinese script dictionary [12] to the previous accuracy analysis testing cases from The Balinese Alphabet writing rules and examples document [13]. As main contribution in this research area, this method was considered as the first Latin-to-Balinese script transliteration method that utilizing Bali Simbar Dwijendra font.

Not so many references in this research area. Mostly utilized Bali Simbar-B font, except one pioneering work by the authors that utilized Noto Sans Balinese font [14]. Sartini et al. [15] has developed a Latin-text to Balinese-script-digital-image converter method on Delphi-based desktop application. The output Balinese script was retrieved from pre-collected images that were captured previously from Bali Simbar-B font display at word processor. Arimbawa et al. [16] has developed a Latin-to-Balinese script transliteration method on C#-based desktop application where the output Balinese script pattern was configured to be written by the robotic system. There are also two other methods on Android mobile application, each was called Belajar Aksara Bali (Learning Balinese Script) [17], and Transliterasi Aksara Bali (Balinese Script Transliteration) [18].

On all of the existing Latin-to-Balinese script transliteration method based on Bali Simbar-B font [19], Authors' work [4] has the best accuracy result accuracy up to 98% (148 of 151) testing cases of The Balinese Alphabet writing rules and examples document [13] by Sudewa, as a project script committee related to the proposal by Eversen and Suatjana [20] for encoding the Balinese script in ISO [21].

II. METHOD

This method has accommodated seventeen kinds of special words [14] that were identified as part of 151 testing cases of The Balinese Alphabet writing rules and examples document [13].

A. The Design Pattern

This method used Model-View-Controller design pattern [22][23], as shown by Fig. 1. That design pattern was implemented by using Ionic framework [24], as a hybrid application development environment that make it possible to use web programming language, involve HyperText Markup Language (HTML), Cascading Style Sheets (CSS), and Javascript, to develop multi-target application, either as web application or mobile application on Android or IOS [25].

Model was implemented by using Javascript (JS) file, as repository for the words belong to seventeen kinds of special words [11][14]. *Dictionary* data structure [26] was used in application memory as a place to hold data from that JS file. View was implemented by using HTML, for the web/mobile application User Interface. Controller was implemented by using JavaScript file, for the transliteration algorithm and as controller between Model and View.
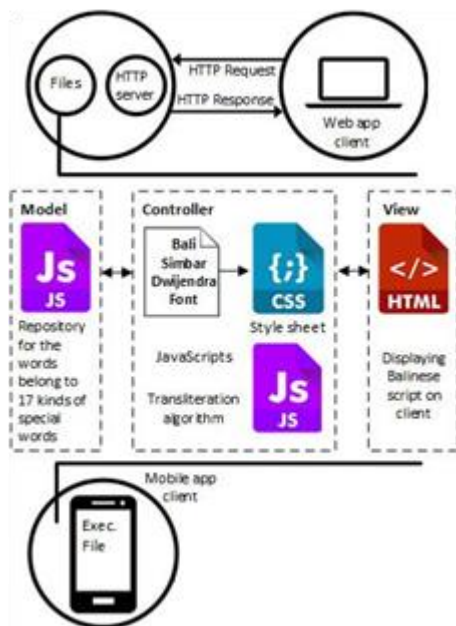
Model or data model used as a reference by the transliteration algorithm. There are several models in this algorithm: 1) data model for cleaning strings of characters thatare not needed in transliteration and preprocessing foreign characters that are not in Balinese script; 2) data model for changing strings in detecting the use of gantungan and also adjusting to the rules of writing Balinese script; 3) data model for replacing strings if there are several characters stacked with each other so that the glyph must be replaced to match the rules for using the Bali Simbar Dwijendra font; 4) dictionary of special words that do not follow the rules of writing Balinese script in general. In the fourth model, the method uses keywords and values.

B. The algorithm

The algorithm consists of 20 successive character replacement processes which are divided into 3 iteration groups. Algorithm consider several factors, i.e.: 1) the writing rules (*uger-uger*) and exceptions (*pasang pageh*) of the Balinese script; 2) rendering rules of Bali Simbar Dwijendra font characters; 3) complex behavior of the Balinese script; 4) dictionary data structure to accommodate seventeen kinds of special words that have different writing. The overall algorithm can be seen in Fig. 2 and one

example of the data model used in the second iteration can be seen in TABLE I.

Fig. 2. The algorithm

Table I. Data model of the 2nd iteration process

First Array			Second Array								
	L	L		L	B		L	B		L	B
0	a	45	2	0			45	Đ	Đ	90	>	>
1	ā	46	3	1	o	O	46	Ñ	Ñ	91	1	2
2	i	47	4	2	i	I	47	O	Ò	92	2	3
3	ī	48	5	3	I	I	48	uæ	Uæ	93	3	4
4	e	49	6	4	)	)	49	U	Ù	94	4	5
5	u	50	7	5	u	U	50	P	P	95	5	6
6	ü	51	8	6	U	U	51	B	ß	96	6	7
7	e	52	9	7	c	E	52	à	A	97	7	8
8	è	53	0	8	E	E	53	á	Ä	98	8	9
9	o	54	ṁ	9	cjo	e|o	54	ä	Ä	99	9	10
10	ö	55	m	10	Eo		55	æ		100	0	
11	h	56	E	11	h	H	56	ć	É	101	Ä	Ä
12	n	57	I	12	n	N	57	ĉ	Ė	102	Æ	Æ
13	c	58	Ö	13	c	C	58	ñ	Ñ	103	Ē	.
14	r			14	r	R	59	Å	Å	104	I	ı
15	k			15	k	K	60	ó	ò	105	Ü	Û
16	d			16	d	D	61	Ő	Ô	106	i	i
17	t			17	t	T	62	ò	ò	107	i	i

First_Array			Second_Array							
	L	L		L	B		L	B	L	E
18	s		18	s	s	63	ö	Ó	10 8	!
19	w		19	w	w	64	×	×	10 9	i
20	l		20	l	L	65	¥	¥	11 0	¢
21	m		21	m	M	66	ı	Ä	11 1	A	Ä
22	g		22	g	G	67	¶	Ė	11 2	I	Í
23	b		23	b	B	68	z	z	11 3	U	Ů
24	ñ		24	\	\	69	E	È	11 4	.	.
25	p		25	p	P	70	ü	¡Ä	11 5	'	'
26	j		26	j	J	71	A	Á	11 6	#	±
27	v		27	v	Y	72	ö	Ò	11 7	§	§
28	z		28	z	Z	73	÷	÷	11 8	%	%
29	x		29	x	X	74	÷o	÷ o	11 9	&c	&
30	d		30	a	a	75	A)	Ä)	12 0	×	"
31	t		31	q	q	76	»	»	12 1	©	»
32	t		32	.	.	77	»o	»o	12 2	¡	¡
33	s		33	]	]	78	6	7	12 3	ö	.
34	s		34	[	[	79	»	»	12 4	Ė	Ė
35	f		35	f	f	80	O	O	12 5	Í	Í
36	b		36	v	v	81	Oo	O o	12 6	ô	ô
37	p		37	l	l	82	•	•		
38	¾		38	¾	¾	83	(	(		
39	¢		39	I	I	84	;	;		
40	ļ		40	o	o	85	/	,		
41	.		41	A	A	86	.	.		
42	-		42	A	A	87	-	-		
43	:		43	Ç	Ç	88	:	:		
44	1		44	È	È	89	<	<		

L – Latin; B – Balinese

In the early stages of the development, the algorithm using the Bali Simbar-B font [10] as a base, then changed to the Bali Simbar Dwijendra font [9]. Some of the reasons choosing the Bali Simbar Dwijendra font are: 1) additional two characters have been added which did not yet exist, namely the character of the *ca laca* consonant and sound killer (*gantungan*) of character *ka mahaprana* (TABLE II); 2) clearer font appearance and more proportional size (TABLE III).

Table II. Additional Characters Of Bali Simbar Dj Font

No	Character	Bali Simbar DJ
1	*Ca laca*	œ
2	*Gantungan Ka Mahaprana*	Ž

Table III. Comparison Of Bali Simbar-B And Bali Simbar Dj On The Same Font Size 10

Bali Simbar-B	Bali Simbar DJ
Ák×r bli	Ák×rbl

C. The testing

The test was based on the example of The Balinese Alphabet document [13]. There are 151 cases where some have examples to be tested, and others do not have examples. For those that do not examples, their corresponding 47 examples were taken from the existing Balinese script dictionary from the Bali Province government [12]. In total there are 198 test cases. The addition of 47 cases can be seen in TABLE IV, while 198 test cases can be seen in TABLE V.

The addition of 47 test cases from the dictionary begins with searching for a maximum of 3 words from the dictionary that represents each case. A case that has more than one word will choose one word to represent the test case, where the word chosen is a word that has relevance to other test cases (see note column). Test cases where their example were not found in [12] were not examined in this study but in general the algorithms were able to accommodate these cases. Latin text "ch" which does not start with a consonant will be shown as consonant *cha laca* (œ) character "konsonan + ö" like "kö" will appear as *pepet tedong* (k)) , o"rö" will appear as *rerepa tedong* (Ïo) and so "lö" will appear as *lelenga tedong* (ò²).

Table IV. Additional Words For Test Cases

No	Cases	Word		Special Word Type
		Latin	Balinese	
Aksara Swalalita Gantungan and *Gempelan*				
1	na	pianakne	pênekÂ.	6th
2	ca	bencana	eb zÇn.	
3	ra	adri	ÁdÉi.	1st
4	ka	nangka	n\Ð.	
5	da	anda	h nÑ.	
6	ta	acintya	Áci nÓí.	1st
7	sa	angseh	he\uæ; .	
8	wa	iswara	÷lÙr .	1st and 7th

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No	Cases	Word (Latin)	Word (Balinese)	Special Word Type
9	la	mlajah	mÞj;.	
10	ma	atma	Átß.	1st
11	ga	anggada	Á\ád .	1st
12	ba	ambe	hemã.	
13	nga	jemet ngempu	ejemetåmæu	
14	pa	ampas	h mæs/ .	
15	ja	banjar	b zé(.	
16	ya	wahyu	w hë .	
17	nya	ajnyana	Ájñn.	1st

Aksara Suara

No	Cases	Word (Latin)	Word (Balinese)	Special Word Type
18	ā	ādipati	õdi p ti	1st
19	i	Budi	bu di.	
20	ī	Dīra	aI r.	7th
21	u	Batur	b tu(.	
22	gantungan + u	Ambu	h mã¡.	

No	Cases	Word		Special Word Type
		Latin	**Balinese**	
23	ū	Sūrya	sU(y.	
24	gantungan + ū	beten būmi	ebet nä¢	7th
25	e	aden	hed n/ .	
26	ai	wesia	Ew]ê	4th and 7th
27	o	abot	hebo t/	
28	au	gora	EGÿ r .	
29	ĕ	acĕp	h c) p/.	
30	ö			Not tested, example words was not found.

Letter   Combination   – *vowel sign Gantungan* and *Gempelan*

No	Cases	Word (Latin)	Word (Balinese)	Special Word Type
31	rĕ	ngatrĕg	\t»g/.	
32	rö			Not tested, example words was not found.
33	lĕ	blĕcĕk	bÞ) c) k/	
34	lö			Not tested, example words was not found.

Aksara *Swalalita Gantungan*

No	Cases	Word (Latin)	Word (Balinese)	Special Word Type
35	ṇa	wisnu	wisÅ¡.	7th
36	dha	pedanda	ep dxÒ.	7th
37	tha	astiti	h sÔi ti.	7th
38	ṭa	agastya	Ág sÔí.	1st and 7th
39	ṣa	wangsa	w\Ö.	7th
40	śa	paksi	p k×i.	7th
41	gha	langgana	l\¥n	7th
42	bha	kumba	ku mä.	7th
43	pha	paras palguna	p rsèlá¡	7th

Consonant sign

No	Cases	Word (Latin)	Word (Balinese)	Special Word Type
44	Cecek	adeng	hed*.	

No	Cases	Word (Latin)	Word (Balinese)	Special Word Type
	(ng)			
45	Surang (r)	amerta	Áem(t .	1st
46	Bisah (h)	aduh	h du;.	
47	Adeg-adeg (.)	adat	Ád t/ .	1st

Miscellaneous

No	Cases	Word (Latin)	Word (Balinese)	Special Word Type
48	kha	karad	¼ rd/	
49	cha	ica	hi cÈ.	
50	Gantungan kha	banten katur	benÓnŽtu	

Word with foreign consonant

No	Cases	Word (Latin)	Word (Balinese)	Special Word Type
51	z	ijazah	hi j s;	

TABLE V. TESTING DATA FROM THE BALINESE ALPHABET DOCUMENT PLUS INDEPENDENT TESTING AND GANTUNGAN/GEMPELAN TESTING

No	Cases	Type	Testing Cases
1	1-18	Basic syllables *(Aksara Wresastra)*	ha na ca ra ka da ta sa wa la ma ga ba nga pa ja ya nya
	19-45	Basic syllables *(Aksara Wresastra)*	pianakne, bencana, adri, nangka, anda, acintya, angseh, iswara, mlajah, atma, anggada, ambe,

No	Cases	Word		Special Word Type
		Latin	**Balinese**	
23	ū	Sūrya	sU(y.	
24	gantungan + ū	beten būmi	ebet nä¢	7th
25	e	aden	hed n/ .	
26	ai	wesia	Ew]ê	4th and 7th
27	o	abot	hebo t/	
28	au	gora	EGÿ r .	
29	ĕ	acĕp	h c) p/.	
30	ö			Not tested, example words was not found.

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No	Cases	Word (Latin)	Word (Balinese)	Special Word Type
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32	rö			Not tested, example words was not found.
33	lĕ	blĕcĕk	bÞ) c) k/	
34	lö			Not tested, example words was not found.

Aksara *Swalalita Gantungan*

No	Cases	Word (Latin)	Word (Balinese)	Special Word Type
35	ṇa	wisnu	wisÅ¡.	7th
36	dha	pedanda	ep dxÒ.	7th
37	tha	astiti	h sÔi ti.	7th
38	ṭa	agastya	Ág sÔí.	1st and 7th
39	ṣa	wangsa	w\Ö.	7th
40	śa	paksi	p k×i.	7th
41	gha	langgana	l\¥n	7th
42	bha	kumba	ku mä.	7th
43	pha	paras	p rsèlá¡	7th

		palguna		
Consonant sign				
44	Cecek (ng)	adeng	hed*.	
45	Surang (r)	amerta	Áem(t .	1st
46	Bisah (h)	aduh	h du;.	
47	Adeg-adeg (.)	adat	Ád t/ .	1st
Miscellaneous				
48	kha	karad	¼ rd/	
49	cha	ica	hi cÈ.	
50	Gantungan kha	banten katur	benÓnŽtu	
Word with foreign consonant				
51	z	ijazah	hi j s;	

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III. RESULTS AND DISCUSSIONS

From 198 cases tested in the algorithm, 195 cases can be well transliterated by algorithm with the percentage accuracy of the algorithm reaching 98%. In the early stages of developing the algorithm [4] it also produced 98% accuracy from 151 test cases based on the same testing document. Execution time for relatively more complex sentence case type (see case 198 at TABLE V) gave relatively real time result at 10.99ms on average of triple measurements on Intel(R) Core(TM) i7-4600U CPU @ 2.10GHz platform with 8 GB RAM and Windows 7 64-bit OS. TABLE VI shows the results of the overall test.

Table VI. Summary Of Test Results

No	Result	No	Result	No	Result	No	Result
1	√	53	√	105	√	157	√
2	√	54	√	106	√	158	√
3	√	55	√	107	√	159	√
4	√	56	√	108	√	160	√
5	√	57	√	109	√	161	√
6	√	58	√	110	√	162	√
7	√	59	√	111	√	163	√
8	√	60	√	112	√	164	√
9	√	61	√	113	√	165	√
10	√	62	√	114	√	166	√
11	√	63	√	115	√	167	√
12	√	64	√	116	√	168	√
13	√	65	√	117	√	169	√
14	√	66	√	118	√	170	√
15	√	67	√	119	√	171	√
16	√	68	√	120	√	172	√
17	√	69	√	121	√	173	√
18	√	70	√	122	√	174	√
19	√	71	√	123	√	175	√
20	√	72	√	124	√	176	√
21	√	73	√	125	√	177	√
22	√	74	√	126	√	178	√
23	√	75	√	127	√	179	√
24	√	76	√	128	√	180	√
25	√	77	√	129	√	181	√
26	√	78	√	130	√	182	√
27	√	79	√	131	√	183	√
28	√	80	√	132	√	184	√
29	√	81	√	133	√	185	√
30	√	82	√	134	√	186	√
31	√	83	√	135	√	187	√
32	√	84	√	136	√	188	√
33	√	85	√	137	√	189	√
34	√	86	√	138	√	190	√
35	√	87	√	139	√	191	√
36	√	88	√	140	√	192	√
37	√	89	√	141	√	193	√
38	√	90	√	142	√	194	√
39	√	91	√	143	√	195	x
40	√	92	√	144	√	196	x
41	√	93	√	145	√	197	x
42	√	94	√	146	√	198	√
43	√	95	√	147	√		
44	√	96	√	148	√		
45	√	97	√	149	√		
46	√	98	√	150	√		
47	√	99	√	151	√		
48	√	100	√	152	√		
49	√	101	√	153	√		
50	√	102	√	154	√		
51	√	103	√	155	√		
52	√	104	√	156	√		

It shows the check mark states the transliteration results provided by the algorithm according to those in the document while the cross means the algorithm does not succeed in producing the same transliteration as the test document.

In three (195-197) cases that failed to be tested were cases related to the use of abbreviations namely "Be Pe Da Bali", "Ba Pe Da Bali", "Ba Pa Da Bali" must be translated in the same way that is .eb,ep,ed,b li(read:.. /be/, /pe/, /de/, bali.) can't be done. Writing Balinese script itself does not recognize the use of spaces and capital letter markers so there is no method in Balinese script to recognize a word as an

abbreviation. The use of a data dictionary to cope with this case is also not recommended because the number of abbreviations alone cannot be determined and will cause an overflow in the dictionary which will result in slow transliteration. Basically transliteration itself only switches characters from one type of script to another according to how the original script is written without regard to the meaning of the word itself. Tackling this, transliteration will produce better results if the source text is written according to how the text is spoken, for example the abbreviation "BRI" is pronounced "/ be /, / er /, / i /," then Latin text writing is translated into script Bali becomes ". be, er, hi,. "(the dot beginning and ending signifies an abbreviation for Balinese script) so that the text of the Balinese script becomes .eb,eh(,hi. In,.addition to testing the 198 cases above, tests were also carried out on several special word groups in the document The Balinese Alphabet, the algorithm had successfully transliterated all the special words contained in the test document. Fig. 3 shows an example of the results of the transliteration of the 2nd and 5th special word groups.
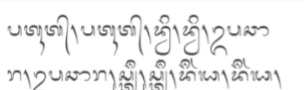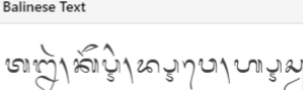
Fig. 3. 2nd and 5th kind of special word transliteration result

IV. CONCLUSION AND FUTURE WORK

Latin text transliteration algorithms into Balinese script using the rule-based string replacement method and dictionary data structure based on Bali Simbar Dwijendra font have been successfully developed with accuracy reaching 98% (195 out of 198 cases).

Things that can be done in further research to improve the accuracy of this algorithm include: 1) Accommodating the input of other special words that are outside The Balinese Alphabet document because the numbers are very large and dynamic, including words found in the existing Balinese script dictionary from the Bali Province government; 2) Implementing semantic transliteration, for an example word "Om" beside means as a symbol of God, it also means as uncle, which has different transliteration result depends on the semantic context; 3) Developing methods to detect use of *pangangge tengenan cecek* in the middle of a word that is currently still handled with a dictionary data structure; and 4) Detecting phrases that are abbreviations in Balinese.

V. ACKNOWLEDGMENT

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