Pasang Aksara Bot: A Balinese Script Writing Robot using Finite State Automata Transliteration Method

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Abstract. Bali is a world tourism destination known for its cultural riches. Balinese culture is a legacy of the world's riches that must be preserved. In the development of the world of education and technology today, there have been many efforts to preserve Balinese culture such as researches used to document the Balinese culture so this culture can still be maintained. One study for the preservation of Balinese culture in the field of technology is the application of Balinese script authors. Balinese script is one of the traditional Indonesian archipelago that developed on Bali. Because its use is limited to a narrow scope, so in everyday use, most Balinese script has been replaced with Latin letters. Therefore this research is focused to make conservation effort to Balinese script with robot technology. Robot is a tool that is a combination of mechanical circuits and electronics circuits. The robot that developed in this research is a robot that can write balinese script with design resembles human arm. In this research for connectivity using USB and on construction platform using Makeblock and mDraw application is a graphics program developed based on open source python. By developing the transliteration application of the script, it can be converted from .png generated into the form .svg or vector as input mDraw and give the command to the robot to write the transliteration result on a piece of paper. In this paper a new idea has been proposed to implement the robot on cultural preservation and Balinese script education. This research has developed a robotics system that can write Balinese Script. This robotic arm was successfully tested with 60% (21 glyph) categorized as very good, 37.14% (13 glyph) categorized as good, and 2.86% (1 glyph) enough. This research was developed on accuracy analysis of transliteration result and result of writing robot to paper. Through the experiment, there was an accuracy of 40.72% for the correct test count and 59.28% for the number of false tests of 1137 words on thirteen types of special words.

1. Introduction
Cultural heritage should not be drowned by age circles and technological developments. Some efforts have been made and are still processed by experts who focus on the values contained in Balinese culture, including Balinese script. Balinese script is a traditional script developed in Bali-Indonesia.

The Balinese language (“Basa Bali”) is the native language of nearly 3 million people in Bali and the western part of the neighboring island Lombok. Bali is a very popular tourist destination, and famous for its rich art and culture. Because Bali is one province of Indonesia, the people of Bali use...
the Indonesian language as the official language in schools, government offices, and other formal institutions. For the native Balinese, the Balinese language is still popular to use in daily life. The language is commonly written in two different scripts: the Balinese script and the Latin script. This article discusses the history of the Balinese script and the modern use of the script at the present time. The History of The Balinese script is without doubt derived from Devanagari and Pallava script from India. The shape of the script shows similarities with southern Indian scripts like Tamil. The concept of syllable also found in other South/Southeast Asian scripts, such as the modern Devanagari, Tamil, Thai, Lao, and Khmer scripts. The Balinese script closest sibling is the Javanese script, which have rectangular form of font shape compared to round shape of Balinese script1.

The commonly used script is also called wrestra script. It consists of 47 characters, including 14 vowels and 33 consonants (wianjana script), Balinese usually only use 18 wlanjana characters. In the last 3 years, several studies have been conducted on culture. One of the areas of computer science study applied to culture is robotics. The basis of this research is research conducted by Padma Nyoman Crisnapati2 entitled “Mengendalikan Lego NXT Robo Laptop Secara Remote Via Bluetooth Dan Wifi Berbasis Webcam”. The study discusses the remote system for controlling the Lego Mindstorm NXT robot. Furthermore, developed by Putu Devi Novayanti3 by making a prototype of robot numerals and latin letters in the study robots can produce latin characters. The results of this study can be seen in Figure 1. After that the robot was re-developed by I Gusti Ngurah Putra Arimbawa4 which is “Pengembangan Robot Penulis Karakter Aksara Bali Berbasis NXT-G Dengan Lego Mindstorm NXT” is a research about Robot writer Balinese script character. However, in the study the character of Balinese script that can be written by the robot is still less smooth, robot control system that is still not efficient in selecting and input script one by one for written robot. The following results can be seen in Figure 2.

But on its application, the mechanics rather than the prototype of the author’s robots are still limited by the use of three motors only. This causes the degree of freedom rather than robots is very limited. In addition, the robot control system is still not efficient that is choosing and input each scripts to be written. Based on these facts required a development of robots that resemble the human arm to be able to write as a human do. This study focuses on the results of writing Balinese script that is regular, not in the form of tilt and written script size has the same size (consistent) by using robot mDrawbot kit. By using mDrawbot, robots have more degrees of freedom. This will affect the form of a neat and balanced script.

Robot control system that will be developed based on previous research that has been done by G. Indrawan5. Entitled “Pasang Aksara: A Latin-to-Balinese Script Transliteration System in HTML Using Unicode Bali Simbar True Type Font”. In the research has been produced a web-based application that can perform the transliteration of Latin (Balinese) into Balinese script. The output of the transformation program is a .png image. With the results of. Png is a constraint to the process of writing, this is because the robot can only read the format of the image vector (.svg). Therefore it is necessary to develop a conversion module from .png into .svg. The .svg result will be input to mDraw application and the robot to write on a piece of paper.

![Figure 1. Character Writing Robot by Putu Devi Novayanti](Image1)

![Figure 2. Balinese Script Writing Robot by I Gusti Ngurah Putra Arimbawa](Image2)
2. Experimental

In the process of transliteration of Latin script into Balinese script is used method of Finite State Automata (FSA). FSA is a mathematical model that can accept input and output output. FSA has a finite state and can move from one state to another state based on input and transition function. The FSA has no storage or memory, can only remember the current state.

There are two levels of FSA used in this study. At the first recognizable level are patterns V, K, and KV. The FSA's recognition to a level becomes an input to the next level of the FSA. In Figure 4 the first tiered FSA transition diagram is depicted. At the second level the FSA can recognize 12 syllables in the V, VK, KV, VKK, KKV, KKKV, KKVKK, KKKVK, KKKVK, and KVKKK patterns. In Figure 5 the second level FSA transition diagram is depicted.

Designing Software Architecture is done to prepare the design of software architecture Robot control system in which there are each Interface controller system robot, robot communication system and robot writing system. The initial stage of the user provides input in the form of Balinese language sentence in Latin script. Then the input will be transliterated through a web-based application and generate output in the form of .png files. Outputs that are still in .png will be automatically converted to .bmp (imagick) which will then be input for potrace to convert to .svg. The process can be seen in Figure 5.
Then after that mdraw application will automatically open and then manually user will make connection settings through COM port to robot. After successfully connected eat the next thing to do the user is to select a svg image and then adjust the position than the image on the mDraw GUI. If it is appropriate, then the user pressing the send button to instruct the robot to write a Balinese script on the paper. System overview can be seen in Figure 7.

**Figure 5. Software Architecture**

**Figure 6. System Overview**

**Figure 7. Pasang Aksara Bot**
Based on figure 8 can be seen a mechanical system rather than a robotic arm that resembles a human arm. The main Controller of this robot is MakeBlock Orion with AC input 100-240V 0.6 A and DC output of 12V 2.0 A. For propulsive Bot Counter use two stepper motors and two motor driver as arm drive. While on the pen there is a servo motor and driver as a driving up and down rather than a pen.

3. Result and Discussion

| No | Testing     | Library | Process          | Result |
|----|-------------|---------|------------------|--------|
| 1  | PNG to BMP  | Imagick | Automatic on click | Success |
| 2  | BMP to SVG  | Poteace | Automatic on click | Success |

In this discussion, we will discuss two stages of testing of the converted results from .png to .bmp and then .bmp to .svg. The first test is done on the convention process from .png to .bmp using imagick library. The conversion process is done by giving the white background on the png image and then the grayscale process, while the transliteration and the result of the conversion to bmp can be seen in Figure 8 and 9 (test succeed). A second test is performed to test the conversion results from a .bmp image to .svg. In the second test it is done with .bmp as input and the result of .svg can be seen in Figure 10 (test succeed).

![Figure 8. PNG Transliteration Result](image)

![Figure 9. PNG to BMP Conversion Result](image)

![Figure 10. BMP to SVG (Vector) Conversion Result](image)

![Figure 11. Techniques of determining errors on the results of writing robots.](image)

After testing the results of the conversion of images, then tested the results of writing to the robot when compared with the results of writing web application script (Bali simbar.ttf) and the conversion results .svg. The result of the bali simbar font size (.svg) used in this test is 200 pt. The error
measurement technique used in writing results than the author's robot can be seen in the Figure 11 and table 5.

Categorization of the results of writing a robot is to see from the number of errors that exist in writing, the category is divided into 5 (Very Good, Good, Fair, Less, Very Less). The categorization can be seen in table 5. From the results of 35 tests in table 4 above obtained the results of 21 robot writing has been on very good predicate, while 13 are in good category and 1 class enough category. So it can be said 60% of robot writing is categorized very good, 37.14% is categorized good, and 2.86% is categorized into enough. The existence of a scratch on each glyph is written due to the process of raising and lowering the pen that is too fast resulting in scratches that are not in accordance with svg given.

| Category     | Upper Error Limit | Lower Error Limit |
|--------------|-------------------|-------------------|
| Very Good    | 0                 | 2                 |
| Good         | 3                 | 5                 |
| Enough       | 6                 | 9                 |
| Poor         | 10                | 12                |
| Very Poor    | 13                | 15                |

The next test is a writing test using a sentence consisting of several characters and words. Here is the phrase used for the test: "Ada katuturan satua: I Kambing tekén I Macan. Sedek dina Redité, I Macan katemu ngajak I Kambing di tengah alasé wayah. Ditu I Kambing nagih amaha baan I Macan.". The bali simbar font size used is 130 pt with space 1.7 pt and paper size F4 obtained results as in figure 12. Then tested differently by using two words "aksara bali "but with the size The larger font is 210 pt with a space of 2 pt and the size of F4 paper is obtained as shown in figure 13. In figure 14 can be seen the test results using one sentence "om awignamastu" font size 260 pt, pt spacing and F4 paper size.

![Figure 12](image1.png)

**Figure 12.** First Results Balinese Script Writing Robot on F4 paper size

![Figure 13](image2.png)

**Figure 13.** Second Results Balinese Script Writing Robot on F4 paper size

![Figure 14](image3.png)

**Figure 14.** Third Results Balinese Script Writing Robot on F4 paper size
In addition to testing the robot writing results on a paper, also conducted an accuracy test for the transliteration application results. There are thirteen types of special words used as a test that can be seen in Table 3.

| Type | Explanation |
|------|-------------|
| 1    | The group of words in which the vowels at the beginning of the word are specifically transliterated using independent vowels. For example: Akśara (letter). |
| 2    | A group of words in which the difference in long vowel writing (ā, ī, ū, or ō) refers to one meaning and should be transliterated equally. For example: Kādēp (sold) - Kadēp (sold). |
| 3    | The group of words in which the difference in vowel writing ē refers to one meaning and should be transliterated equally. For example: Jēro (house) - Jero (house). |
| 4    | The group of words in which the vowel is a diphthong ai - ē or au - ō should be transliterated equally. For example: Daitya (giant) - Dētya (giant). |
| 5    | A group of words in which differences in the writing of ra repa (rē or rō) or la lenga (lē or lō) refer to one meaning and should be transliterated equally. For example: Talēr (also) - Taler (also). |
| 6    | The group of words in which the difference in semi-vowel writing (ra, rē, rō, ua, la, or he) refers to one meaning and should be transliterated equally. For example: Briag (intense) - Bryag (intense). |
| 7    | The group of words in which the difference in the writing of akśara śwalalita (ṇa, dha, tha, ṭa, ṣa, śa, gha, bha, or pha) refers to one meaning and should be transliterated equally. For example: Bhiśama (decision) - Bhisama (decision). |
| 8    | The group of words where the syllable sound ends with another marker (ulu candra or ulu ricem) as part of the marker of the modre (sacred symbol). For example: Om (holy letter). |
| 9    | The group of words in which the vowel a at the end of a word can be pronounced (once written) as a vowel ĕ. Though different in writing, the word pair should be transliterated equally. For example: Sĕkala (real) - Sĕkalĕ (real). |
| 10   | The group of words in which the vowel combination can be written as a vowel-consonant combination. Though different in writing, the word pair should be transliterated equally. For example: Kśatria (knight) – Kśatriya (knight). |
| 11   | A group of words where one consonant or two of the same consonant actually have one sound (dwita). Though different in writing, the word pair should be transliterated equally. For example: Utama (main) - Uttama (main). |
| 12   | Foreign word group. For example: Bank. |
| 13   | The group of words in which the difference in writing of the syllable assimilation combinations becomes nga refers to one meaning and should be transliterated equally. For example: wianjana (consonant) - wyanjana (consonant). |

The results obtained are accurate 40.72% (of 463 words) for the correct test count and 59.28% (of 674 words) for the number of false test of 1137 words on thirteen types of special words. Accuracy test results can be seen in Table 4.
Table 4. Results of the Testing of Special Word Accuracy

| Special Word Kind | Number of Word Tested (word) | Number Success (word) | Number Failed |
|-------------------|-----------------------------|-----------------------|---------------|
| 1                 | 100                         | 59                    | 41            |
| 2                 | 100                         | 0                     | 100           |
| 3                 | 100                         | 100                   | 0             |
| 4                 | 25                          | 0                     | 25            |
| 5                 | 100                         | 100                   | 0             |
| 6                 | 100                         | 0                     | 100           |
| 7                 | 100                         | 100                   | 0             |
| 8                 | 12                          | 1                     | 11            |
| 9                 | 100                         | 100                   | 0             |
| 10                | 100                         | 1                     | 99            |
| 11                | 100                         | 0                     | 100           |
| 12                | 100                         | 1                     | 99            |
| 13                | 100                         | 1                     | 99            |
| **TOTAL**         | **1137**                    | **463**               | **674**       |

4. Conclusion and Future Work

Interaction between human and machine is an important factor of developing a technology for cultural preservation especially Balinese Script. This research has developed a robotics system that can write Balinese Script. This robotic arm was successfully tested with 60% (21 glyph) categorized as very good, 37.14% (13 glyph) categorized as good, and 2.86% (1 glyph) enough. And obtained the result of transliteration accuracy 40.72% (from 463 words) for correct test amount and 59.28% (from 674 words) for wrong test count from 1137 word on thirteen kinds of special word in transliteration application.

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References

[1] I B Adi Sudewa. “Contemporary use of the Balinese script. Http://www. unicode.org/L2/L2003/03118-balinese.pdf. 2003. [Accessed: 24 January 2017]

[2] P N Crisnapati. “Mengendalikan Lego NXT Robo Laptop Secara Remote Via Bluetooth Dan Wifi Berbasis Webcam”. Tugas Akhir. Jurusan Teknik Informatika, Institut Teknologi Sepuluh Nopember Surabaya. (2009)

[3] Putu Devi Novayanti. "Pengembangan Robot Penulis Karakter Berbasis NXT-G Dengan Lego Mindstorm NXT". Universitas Pendidikan Ganesha. Singaraja. (2012)

[4] I. G. N. P. Arimbawa, M. W. A. Kesiman, I. G. M. Darmawiguna. Pengembangan Robot Penulis Karakter Aksara Bali Berbasis NXT-G dengan Lego Mindstorm NXT. Jurnal Nasional Pendidikan Teknik Informatika (JANAPATI), ISSN, 2089-8673. (2012).

[5] Indrawan, G., Crisnapati, P.N., et al. ‘Pasang Aksara: A Latin-to-Balinese Script Transliteration Web App’ [Online] Available at: http://pasca.undiksha.ac.id/ilkom/pasangaksara/. (2017) [Accessed: 24 January 2017]