# Myanmar Text (Burmese) and Braille (Mu-Thit) Machine Translation Applying IBM Model 1 and 2

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***Abstract*— Braille is a writing system that uses raised dots patterns to read and write characters on paper for people who are visually impaired. Due to the limited availability of braille textbooks, the visually impaired people are facing difficulties to access reading resources. The goal of this paper is to evaluate the quality of IBM alignment models between Myanmar text and one of the Myanmar Braille systems named "Mu-Thit". We also developed a Myanmar Braille (Mu-Thit) parallel corpus (10,262 sentences) based on the Myanmar Basic Education Textbooks. The 10 folds cross-validation experiments were carried out using IBM alignment Model 1 and 2. The results show that the two models handle well for Myanmar text to Braille (Mu-Thit) conversion and vice versa. We analyzed in detail the accuracy of each sentence and n-gram feature from the analysis results of compare-mt based on IBM Model 1 and 2.**

***Index Terms*—IBM Model 1, IBM Model 2, Expectation-Maximization, Machine Translation, Myanmar language (Burmese), Braille (Mu-Thit)**

## I. Introduction

THE main motivation for this research is to investigate the translation performance of IBM Model 1 and 2 for Myanmar Braille and Myanmar text language pair. The IBM model is a series of models with increasing complexity. IBM Model 1 only uses lexical translation, while Model 2 has an additional model for alignment that is not present in Model 1 [13]. Mu-Thit Braille is based on one-to-one mapping of Myanmar words, so it is only compatible with word based statistical machine translation models such as IBM Model 1 and 2. The Braille system was created by Frenchman Louis Braille in 1821. It is a reading and writing method that is widely used by visually impaired people. It contains raised dots that represent the letters of the alphabet. The blind person can read the letters by moving their hand or hands from left to right along each line. A visually impaired person can study the written words by using the braille alphabet. Braille symbols can be written within units of space known as braille cells. In a braille cell, there are six raised dots arranged in two columns with up to three dots. People can raise dots in any of the six positions, creating sixty-four $2^6$ possible characters, including one in which there are no raised dots. As an easier reading, the dots of the cell are numbered from top to bottom, the first column is as 1, 2, 3 and the second column as 4, 5 and 6. There are two types of Braille systems called Mu-Thit and Mu-Haung in Myanmar. The detailed description of Mu-Thit and Mu-Haung is expressed in section 3.

The remainder of this paper is organized as follows. In section 2, we describe the related work. Section 3 briefly introduces Myanmar Braille. Section 4 describes the IBM models. Section 5 presents the overview of experimental setup and results. Section 6 provides the error analysis of each model output in detail. Lastly, we conclude in section 7.

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## II. Related Work

G. Chinnappa and Anil Kumar Singh [3] proposed the implementation of Java Extended word alignment algorithm based on the IBM model. Khin Thandar Nwet [5] developed a Burmese-English parallel corpus aligned by word according to the IBM model. They proposed the corpus-based approach and dictionary lookup approach. They also proposed the word and sentence alignment in Burmese and English language in [6]. Franz Josef Och and Hermann Ney compared many statistical alignment models [4]. Joel Martin, Rada Mihalcea and Ted Pedersen discussed the alignment of words in English, Hindi, Romanian, and Inuktitut parallel text [8]. Maoxi Li and Chengqing Zong published word reordering alignment based on a combination of statistical machine translation systems [7]. In their approach, firstly find a continuous word sequence, and then replace it with some variables. Align variables and words in two sentences with each other and detect the sequence of words that should be reordered. The syllable segmented source language was aligned with the syllable segmented target language using GIZA++ [9]. R. Harshawardhan, Mridula Sara Augustine and Dr K. P. Soman [10] proposed a simplified word alignment algorithm for English-Tamil translation. The word alignment problem is viewed as a simple assignment problem and is formulated as an Integer Linear Programming problem. Jamie Brunning, Adria de Gispert and William Byrne proposed Context-Dependent alignment models for statistical machine translation [11]. These models lead to an improvement in alignment quality, and an increase in translation quality when the alignments are used in Arabic-English and Chinese-English translation. Li and Chengqing Zong [12] presented in word alignment between sentences with different valid word orders, changing the order of the word sequence to make the word order more accurately match the alignment reference.

## III. Myanmar Braille

The first Myanmar Braille script was invented by U Phay Gyi who was a visually impaired person in the 19th century [1]. A new Myanmar Braille script was developed by Father Jackson in 1918. It is based on English Braille characters and pronunciation of Myanmar language. By the leading of the Social Welfare, Relief and Resettlement Department, Grade (1) Myanmar Braille called Mu-Thit was developed in 1967. Its writing order is based on the Myanmar language writing system. In 2005, Father Jackson's Myanmar Braille was also updated by collaboration work of Myanmar Christian Fellowship of the Blind (M.C.F.B), School for the Blind (Kyimyindine) and Ministry of Social Welfare, Relief and Resettlement Department [2]. It is Grade (2) Myanmar Braille called Mu-Haung.

### A. Mu-Thit

Mu-Thit Myanmar Braille is also known as Grade (1) Myanmar Braille. Mu-Thit's writing order is also the same as the handwriting order of the Myanmar language. Although it needs to type more than Grade (2) Myanmar Braille, it is easy to learn the braille script. There are thirty-three consonants, eight vowels, four consonant signs, thirteen special signs, four special characters and ten numbers.

There are also punctuation marks in Myanmar Braille. Some symbols have the same braille script that are highlighted in the Table I. When translating Braille to Myanmar, the same braille script will also have translation errors. Therefore, some of the same braille script errors are shown in the error analysis section.

TABLE I
Myanmar Braille Punctuation marks and symbols

| Punctuation marks and symbols | Myanmar Braille |
|---|---|
| ၊ | ⠒ |
| ။ | ⠲ |
| ( | ⠶ |
| ) | ⠶ |
| [ | ⠠⠶ |
| ] | ⠶⠄ |
| " | ⠦ |
| " | ⠴ |

In Grade (1) Myanmar Braille writing method, syllables are basically formed by combinations of consonant signs or vowels or special signs. When writing conjunct consonants that there is no "tha wai tho: => (ေ◌ )" in the middle of the word, the writing order is the upper character, a conjunct consonants sign ("⠤" in Braille) and then the lower character. For example ဗုဒ္ဓ ("Buddha" in English) for ⠩⠑⠙⠤⠋. If there is "tha wai tho: => (ေ◌ )" in the middle of the word, the writing order is the upper character, a conjunct consonants sign ("⠤" in Braille), "tha wai tho: => (ေ◌ )" and then the lower character. For example သင်္ဘော ("Ship" in English) for "⠹⠐⠱⠃⠁". When writing numbers, there must be included number sign ("⠼" in Braille) before the number because some braille number signs and some consonants are defined with the same script in Myanmar Braille. The followings are some example sentences of Myanmar and Grade (1) Myanmar Braille called Mu-Thit:

my: ပွင့် ဖူး ကြ ချိန် အ မှန် ၊ ဝ သန္တ လေ ချို ဖျန်း ။ ("Budding and blooming on time, Blowing the gentle breeze of the rainy season." in English)

bl: ⠏⠜⠌⠄⠂ ⠈⠥⠆ ⠅⠢ ⠨⠔⠊⠝⠄ ⠣ ⠍⠭⠏⠄ ⠒ ⠺ ⠰⠹⠟⠤⠞ ⠱⠇ ⠨⠔⠊⠑ ⠘⠔⠟⠄⠆ ⠲

my: ကျောင်း သင်္ခမ်း တွင် ဒု ကူ လ နှင့် ပါ ရိ ကာ ရ သေ့ နှစ် ပါး နှင့် သား ဖြစ် သူ သု ဝဏ္ဏ သာ မ တို့ အ တူ နေ ထိုင် ကြ ၏ ။ ("The two hermits named Dukula and Parika lived with their son, Suwunnasama in the hermitage." in English)

bl: ⠱⠅⠔⠁⠌⠄⠆ ⠹⠐⠨⠍⠄⠆ ⠞⠜⠌⠄ ⠙⠑ ⠅⠥ ⠇ ⠝⠭⠄⠂ ⠏⠰⠁ ⠗⠊ ⠅⠁ ⠗ ⠱⠹⠂ ⠝⠭⠎⠄ ⠏⠰⠁⠆ ⠝⠭⠌⠄⠂ ⠹⠁⠆ ⠘⠢⠎⠄ ⠹⠧ ⠹⠑ ⠺⠫⠤⠻ ⠹⠁ ⠍ ⠞⠊⠑⠂ ⠣ ⠞⠥ ⠱⠝ ⠚⠊⠑⠌⠄ ⠅⠢ ⠕ ⠲

my: ၁၉၂၀ ပြည့် ကျောင်း သား သ ပိတ် ကြီး တွင် ဦး ဖိုး ကျား သည် ထင် ရှား သော ခေါင်း ဆောင် တစ် ဦး ဖြစ် သည် ။ ("U Pho-Kyar was a prominent leader in 1920, students' strike." in English)

bl: ⠼⠁⠊⠃⠚ ⠏⠢⠷⠄⠂ ⠱⠅⠔⠁⠌⠄⠆ ⠹⠁⠆ ⠹ ⠏⠊⠞⠄ ⠅⠢⠪⠆ ⠞⠜⠌⠄ ⠰⠑⠪⠆ ⠘⠊⠑⠆ ⠅⠔⠁⠆ ⠹⠷⠄ ⠚⠌⠄ ⠗⠭⠁⠆ ⠱⠹⠁ ⠱⠨⠰⠁⠌⠄⠆ ⠱⠖⠁⠌⠄ ⠞⠎⠄ ⠰⠑⠪⠆ ⠘⠢⠎⠄ ⠹⠷⠄ ⠲

### B. Mu-Haung

Mu-Haung Myanmar Braille is also known as Grade (2) Myanmar Braille. It is a modification of Father Jackson's Myanmar Braille. It consists of special vowels, shortened words and fake consonants. Its writing is based on the Myanmar pronunciation system. Therefore it may cause many ambiguities problems. The Grade (2) Myanmar Braille is faster writing and reading than Grade (1) Myanmar Braille [2]. Grade(2) Myanmar Braille consists of twenty two consonants, eleven vowels, thirteen Thara

Tu (pseudo vowels), twenty Byii Tu (Pseudo Consonant Sign) and shorten words. Some example for Mu-Haung is written as follows:

my: ဖြိုး မောက် (ဖ+◌ြ+◌ိ+◌ု+◌း ◌ေ+မ+◌ာ+က+◌်)

bl: ⠿⠛⠕⠆ ⠍⠬ (ဖြ+အို+◌း မ+အောက်)

my: စည်း လုံး(စ+ည+◌်+◌း လ+◌ံ+◌ု+◌း)

bl: ⠎⠪⠆ ⠇⠉⠆ (စ+အီ+◌း လ+အုံ+◌း)

my: ရို သေ (ရ+◌ိ+◌ု ◌ေ+သ)

bl: ⠗⠕ ⠹⠱ (ရ+အို သ+အေ)

## IV. Methodology

In this section, we describe the methodology used in this machine translation experiment. In the experiment of this paper, the first two IBM models are used. The first statistical machine translation models were developed at IBM research in the 1980s. In 1993, Brown et al. developed the five IBM statistical models [20] . The IBM models are sequences of models with increasing complexity, starting with lexical translation probabilities, adding models for reordering and word duplication.

### A. IBM Alignment Model 1

The Model 1 is a word-alignment model that is widely used in working with parallel bilingual corpora. It is a probabilistic generative model, which assumes that the source sentence with the length of the translation is translated into the target sentence (see Algorithm 1). For each output word $e$ that is produced by the model from an input word $f$, define in the translation probability $p(e|f)$ [13]. According to the alignment function a : j $\to$ i, the translation probability for a foreign sentence f = ($f_1$, ..., $f_{lf}$) of length $l_f$ to an English sentence e = ($e_1$, ..., $e_{le}$) of length $l_e$ with an alignment of each English word $e_j$ to a foreign word $f_i$ is shown in equation 1 as follows:

$$p(e,a|f) = \frac{\in}{(l_f+1)^{l_e}} \prod_{j=1}^{l_e} t(e_j|f_{a(j)}) \tag{1}$$

### B. IBM Alignment Model 2

IBM Model 2 solves the problem of alignment using an explicit model based on the position of input and output words (see Algorithm 2). The translation of a foreign input word in position $i$ to an English word in position $j$ is modeled by an alignment probability distribution [13].

$$a(i|j,l_e,l_f) \tag{2}$$

There are two steps in IBM Model 2. The first step is lexical translation step as in IBM Model 1, again modeled by the translation probability $t(e|f)$. The second step is an alignment step. These two steps are mathematically combined to form IBM Model 2 as in equation 3.

$$p(e,a|f) = \in \prod_{j=1}^{l_e} t(e_j|f_{a(j)}) a(i|j,l_e,l_f) \tag{3}$$

### C. The Expectation-Maximization Algorithm

The Expectation-Maximization(EM) algorithm is an iterative learning method that fills in the gaps in the data and trains a model in alternating steps [13]. There are four main steps in EM algorithm: Initialization, Expectation, Maximization and Iteration. The first step is initializing the model and all alignments are equally likely. The expectation step computes the probability of alignments. And then, fill the most likely gap in the data and find the most likely alignments. Then, compute the count collection in the maximization step. Finally iterate these steps until convergence.

The steps of the EM algorithm for IBM model 1 are as follows.

Step 1: Collect all unique words from Myanmar(my)-Braille(br) parallel corpus.

Step 2: Initialize the t(br|my) with the initial probability.

Step 3: Collect the evidence of the Braille word being translated by the Myanmar word.

Step 4: Estimate the new probability distribution t(br|my).

**Algorithm 1** EM training algorithm for IBM Model 1

Input: set of sentence pairs (br,my) // *br is Myanamr braille and my is Myanamr text.*
Output: translation probability t(br|my)

initialize t(br|my) uniformly // *initialize translation probability*
**while** not end of br **do**
  count(br|my) = 0 for all br,my
  total(my) = 0 for all my
  **for all** $my - brpairs$ (br,my) **do**
    **for all** $br - word$ in $br$ **do**
      s-total(br) = 0
      **for all** $my - word$ in $my$ **do**
        s-total(br) += t(br|my)
      **end for**
    **end for**
//*collect counts for evidence that a particular Braille output word br is aligned to a particular Myanmar input word my*
    **for all** $br - word$ in $br$ **do**
      **for all** $my - word$ in $my$ **do**

$$count(br|my) += \frac{t(br|my)}{s - total(br)}$$

$$total(my) += \frac{t(br|my)}{s - total(br)}$$

      **end for**
    **end for**

**end for**
**for all** $my - word$ in $my$ **do** *// estimate translation probabilities distribution by normalizing counts*
**for all** $br - word$ in $br$ **do**

$$t(br|my) = \frac{count(br|my)}{total(my)}$$

**end for**
**end for**
**end while**

The following steps are the working process in IBM model 2.

Step 1: Get the translation probability distribution from IBM model 1.

Step 2: Initialize the alignment probability distribution a(i|j,$l_{br}, l_{my}$) with the initial probability.

Step 3: Simulate normalization and collect counts.

Step 4: Compute the new lexical translation probabilities and alignment probabilities.

**Algorithm 2** EM training algorithm for IBM Model 2

Input: set of sentence pairs (br,my)
Output: probability distributions t (lexical translation) and a (alignment)

carry over t(br|my) from Model 1
initialize $a(i|j, l_{br}, l_{my}) = \frac{1}{(l_{my}+1)}$ for all i,j, $l_{br}, l_{my}$ *// initialize the alignment probability distribution for length of the input sentence Myanmar is denoted as* $l_{my}$ *and the output sentence Braille is* $l_{br}$
**while** not converged **do**
$count(br|my) = 0$ for all i,j, $l_{br}, l_{my}$
total(my) = 0 for all my
$counta(i|j, l_{br}, l_{my}) = 0$ for all br,my
$totala(j, l_{br}, l_{my}) = 0$ for all j,$l_{br}, l_{my}$
**for all** $my - brpairs$ (br,my) **do**
$l_{br} = length(e), l_{my} = length(f)$
**for** $j = 0 \ldots l_{br}$ **do**
$s - total(br_j) = 0$
**for** $i = 0 \ldots l_{my}$ **do**
$s - total(br_j) += t(br_j|my_i) * a(i|j, l_{br}, l_{my})$
**end for**
**end for**
**for** $j = 1 \ldots l_{br}$ **do**
**for** $i = 0 \ldots l_{my}$ **do**
$c = t(br_j|my_i) * \frac{a(i|j,l_{br},l_{my})}{s-total(br_j)}$
$count(br_j|my_i) += c$
$total(my_i) += c$
$counta(i|j, l_{br}, l_{my}) += c$
$totala(j, l_{br}, l_{my}) += c$
**end for**
**end for**
**end for**
t(br|my) = 0 for all br, my
$a(i|j, l_{br}, l_{my}) = 0$ for all i, j, $l_{br}, l_{my}$
**for all** $br$, $my$ **do**
t(br|my)= count(br|my)/ total(my)
**end for**
**for all** $i, j, l_{br}, l_{my}$ **do**
$a(i|j, l_{br}, l_{my}) = \frac{count_a(i|j,l_{br},l_{my})}{total_a(j,l_{br},l_{my})}$
**end for**
**end while**

## V. Experiments

### A. Corpus Statistics

There are many difficulties for Myanmar Natural Language Processing (NLP) researchers because of the lack of data resources. At present, there is no Braille-Myanmar parallel corpus. Therefore, as an experiment, we prepared Mu-Thit Myanmar Braille and Myanmar text parallel corpus from Myanmar Basic Education textbooks which are published by the Ministry of Education. In the Braille-Myanmar parallel corpus, we used 10,262 sentences from "Grade 3" to "Grade 11" of Myanmar Basic Education textbooks. Soft copies of Myanmar Braille textbooks are contributed by the permission of the Yangon Education Center for the Blind. Syllable segmentation for Myanmar was done by using a regular expression (https://github.com/ye-kyaw-thu/sylbreak). And then, we convert the Myanmar sentences into Braille sentences.

### B. Implementation

In the implementation process, we performed 10-fold cross-validation experiments, using approximately 7,800 sentences for training, 1,300 sentences for development and 1,000 sentences for evaluation, respectively. We developed the Perl scripts for IBM Model 1 and 2 are based on algorithms[13]. Using the Perl scripts, we evaluated the translation output. After that, use the compare-mt tool to analyze the results of Model 1 and 2.

### C. Compare-mt

Compare-mt is a tool for holistic comparison and analysis of the results of language generation systems [17]. It implements the aggregate score analysis, the analysis of the accuracy of generation of particular types of words, bucketed histograms of sentence accuracies, extraction of characteristic n-grams for each system and sentence example analysis. The aggregate score analysis gives the overall accuracy of each system by calculating the BLEU. The analysis of the bucketed word accuracy attempts the types of words which can generate each system better than the other. It measures the accuracy of word bucketed by frequency in the training corpus. In the n-gram analysis, compare-mt finds the differences in the n-grams generated by each system, and tries to find that each system is better than the n-grams generated by another system. It calculates the smooth probability of n-gram matches from one system or another by using equation 4 [17].

$$p(x) = \frac{m_1(x) + \alpha}{m_1(x) + m_2(x) + 2\alpha} \tag{4}$$

### D. Evaluation

We used de facto standard automatic evaluation metric Bilingual Evaluation Understudy (BLEU) [18] and the Rank-based Intuitive Bilingual Evaluation Measure (RIBES) [19] for the evaluation of the machine translation output. The average BLEU and RIBES score results for two IBM models are shown in Table II. The RIBES scores are in the round brackets. One of the two IBM Models, the highest scores are highlighted in bold.

TABLE II
AVERAGE BLEU AND RIBES SCORES FOR IBM MODEL 1 AND 2 FOR BRAILLE-MYANMAR AND MYANMAR BRAILLE TRANSLATION

| **src-tgt** | **IBM 1** | **IBM 2** |
|---|---|---|
| br-my | 98.70(0.99805) | **98.77(0.99815)** |
| my-br | 96.01(0.99555) | **96.18(0.99565)** |

Where, "my" stands for Myanmar, "br" stands for Braille, "src" stands for source language and "tgt" stands for target language respectively. According to the BLEU and RIBES scores, IBM Model 2 is slightly better than the Model 1 in both directions.

## VI. ERROR ANALYSIS

In this paper, we analyzed the translated output using Word Error Rate (WER). For making dynamic programming based alignments between reference (ref) and hypothesis (hyp) strings and calculation of WER, we used the SCLITE (score speech recognition system output) program from the NIST scoring toolkit SCTK (Speech Recognition Scoring Toolkit) version 2.4.10 [14]. The formula for WER can be stated as equation 5:

$$WER = \frac{(N_i + N_d + N_s) \times 100}{N_d + N_s + N_c} \tag{5}$$

where $N_i$ is the number of insertions; $N_d$ is the number of deletions, $N_s$ is the number of substitutions, $N_c$ is the number of correct words. The SCLITE program prints confusion pairs and Levenshtein distance calculations for all hypothesis sentences in detail. The WER percentage of IBM Model 1 and 2 for Myanmar to Braille and Braille to Myanmar translations are as shown in Table III. The bold number indicates the lowest WER score. The WER score of IBM Model 2 is lower than the IBM Model 1 in both translation directions. Some translated output errors are shown in the sentence example analysis sections. The underlined words are translated output errors.

TABLE III
AVERAGE WER% FOR IBM MODEL 1 AND IBM MODEL 2 FOR BRAILLE-MYANMAR AND MYANMAR BRAILLE TRANSLATION

| **src-tgt** | **IBM 1** | **IBM 2** |
|---|---|---|
| br-my | 0.65% | **0.6%** |
| my-br | 1.45 % | **1.41%** |

### A. N-gram Analysis for Braille to Myanmar Language

From the results of n-gram analysis, we can investigate the reference and output of each system and find out the occurrences that lead to differences in the accuracy of n-grams. In this compare-mt tool, the minimum and maximum lengths of n-gram are 1 and 4. The smoothing coefficient $\alpha$ is set to 1. Some examples of n-grams analysis are displayed in Table IV and Table V.

TABLE IV
THE N-GRAM ANALYSIS OF IBM 1 IS LARGER THAN THAT OF IBM 2 IN BRAILLE-MYANMAR

| **n-gram** | **match** | **IBM 1** | **IBM 2** |
|---|---|---|---|
| ( | 0.9844 | 62 | 0 |
| ပလ္လင် ( | 0.6667 | 1 | 0 |
| အ တွက် ( | 0.8333 | 4 | 0 |
| ( ရွတ် ဆို ရန် | 0.8000 | 3 | 0 |

TABLE V
THE N-GRAM ANALYSIS OF IBM 2 IS LARGER THAN THAT OF IBM 1 IN BRAILLE-MYANMAR

| **n-gram** | **match** | **IBM 1** | **IBM 2** |
|---|---|---|---|
| ) | 0.01223 | 0 | 80 |
| ဇွန် လ | 0.2500 | 0 | 2 |
| ) စ ပါး | 0.2000 | 0 | 3 |
| ညည်း ညည်း ညူ ညူ | 0.3333 | 0 | 1 |

Table IV shows some examples in which model 1 is more compatible with n-grams than model 2. As in the example of 1-gram analysis "(" matches 62 times in model 1. For example, further analysis showed that the relatively high accuracy of "( ရွတ် ဆို ရန်" for the IBM model 1 was due to the propensity of the IBM model 2 to output incorrectly translated ") ရွတ် ဆို ရန်". The results in Table V represent more matching n-grams in Model 2.

### B. Sentence Example Analysis for Braille to Myanmar Language

We studied the comparison of the results generated by each IBM system using the compare-mt tool. Sentence example analysis calculates the accuracy of each sentence. We performed manual error analysis on compare-mt outputs, and we found five frequent error patterns: "Incorrect Translation Error", "Conjunct Consonant Words Error", "Untranslated Error", "Confusion Word Error" and "Number Error". We analyzed five types of errors that were the most frequent errors from the comparing results of sentence examples are shown in Table VI to Table X. The following are some example sentences for each category.

TABLE VI
INCORRECT TRANSLATION ERROR

| | Output | Sent-BLEU |
|---|---|---|
| Ref | မျက် ရည် သွန် လို့ ဘ ဝင် ညိုး ဇူ လိုင် တစ် ဆယ့် ကိုး ။<br>("Tears are painfully drop down in July 19." in English) | |
| IBM 1 | မျက် ရည် သွန် လို့ ဘ ဝင် ညိုး ဇူ ဇူ တစ် ဆယ့် ကိုး ။ | 78.254 |
| IBM 2 | မျက် ရည် သွန် လို့ ဘ ဝင် ညိုး ဇူ လိုင် တစ် ဆယ့် ကိုး ။ | 100.000 |

where "Ref" is the reference sentence of Braille to Myanmar language and "Sent-BLEU" is BLEU scores of each sentence. In the case of incorrect translation error as shown in Table VI, IBM model 1 translates the reference word "ဇူ လိုင်" ("July" in English) into "ဇူ ဇူ" ("Zu Zu" in English). Therefore the sentence accuracy of IBM model 1 is 78.254. IBM model 2 can be translated correctly, so its sentence BLEU is better than IBM model 1.

TABLE VII
CONJUNCT CONSONANT WORDS ERROR

| | Output | Sent-BLEU |
|---|---|---|
| Ref | တန် ခူး ၊ သင်္ကြန် ၊ အ ဓိပ္ပာယ် ၊ ရေ သပ္ပာယ် ၊ တိ ရစ္ဆာန် ၊ မဏ္ဍပ် ။<br>("Dagu, Thingyan, Meaning, Delivered Water, Animal, Pavilion." in English) | |
| IBM 1 | တန် ခူး ၊ သင်္ကြန် ၊ အ ဓိပ္ပာယ် ၊ ရေ သိင်္ဂုတ္တ ၊ တိ ရစ္ဆာန် ၊ မဏ္ဍပ် ။ | 82.825 |
| IBM 2 | တန် ခူး ၊ သင်္ကြန် ၊ အ ဓိပ္ပာယ် ၊ ရေ သပ္ပာယ် ၊ တိ ရစ္ဆာန် ၊ မဏ္ဍပ် ။ | 100.000 |

The above Table VII shows the conjunct consonant words error. Conjunct consonant means that two consonant letters are stacked together and the second consonant is subscript of the first consonant. IBM model 1 translates the word "သိင်္ဂုတ္တ" ("Singutta" in English) as a replacement for the reference word "သပ္ပာယ်" ("delivered water" in English). So, IBM model 1 cannot translate some conjunct consonants well.

TABLE VIII
UNTRANSLATED ERROR

| | Output | Sent-BLEU |
|---|---|---|
| Ref | ၃ ။ ကာ မိန္ဒ အ မည် ရှိ သော အ မတ်<br>("An member of Parliament named Karmainda." in English) | |
| IBM 1 | ၃ ။ ကာ ⠍⠊⠝⠤⠙ အ မည် ရှိ သော အ မတ် | 70.169 |
| IBM 2 | ၃ ။ ကာ ⠍⠊⠝⠤⠙ အ မည် ရှိ သော အ မတ် | 70.169 |

TABLE IX
NUMBER ERROR

| | Output | Sent-BLEU |
|---|---|---|
| Ref | အ မြင့် ပေ ၃၆၀၀ ခန့် ရှိ သည် ။<br>("It is about 3,600 feet high." in English) | |
| IBM 1 | အ မြင့် ပေ ⠼⠉⠋⠚⠚ ခန့် ရှိ သည် ။ | 59.695 |
| IBM 2 | အ မြင့် ပေ ⠼⠉⠋⠚⠚ ခန့် ရှိ သည် ။ | 59.695 |

In Braille to Myanmar translation, the output must be Myanmar text. However, in Table VIII and Table IX, both IBM Model 1 and 2 came out as braille script instead of Myanmar. Therefore, we refer to these errors as untranslated errors. Table IX shows that both models cannot convert numerical data.

TABLE X
CONFUSION WORD ERROR

| | Output | Sent-BLEU |
|---|---|---|
| Ref | ( က ) ဗိုလ် ချုပ် အောင် ဆန်း သည် ဖြောင့် - - - သည် ။ ( မတ် ၊ မပ် )<br>("General Aung San is righteous.(ma', ma')" in English) | |
| IBM 1 | ( က ( ဗိုလ် ချုပ် အောင် ဆန်း သည် ဖြောင့် - - - သည် ။ ( မတ် ၊ ⠍⠏⠄ ( | 76.479 |
| IBM 2 | ) က ) ဗိုလ် ချုပ် အောင် ဆန်း သည် ဖြောင့် - - - သည် ။) မတ် ၊ ⠍⠏⠄ ) | 72.096 |

In Table X, there are two errors, confusion error and untranslated error. In our confusion word error example, model 1 translates ")" as "(" and "(" is translated as ")" in model 2 because the braille scripts of "(" and ")" are assigned the same script as "⠶"

### C. N-gram Analysis for Myanmar to Braille

The n-gram analysis results from Myanmar to Braille are also evaluated using the compare-mt tool. Some examples of n-grams analysis are displayed in Table XI and Table XII.

TABLE XI
THE N-GRAM ANALYSIS OF IBM 1 IS LARGER THAN THAT OF IBM 2 IN MYANMAR BRAILLE

| n-gram | match | IBM 1 | IBM 2 |
|---|---|---|---|
| ⠱⠵⠁⠴ | 0.8571 | 5 | 0 |
| ⠝⠑ ⠱⠃⠁⠴ | 0.750 | 2 | 0 |
| ⠱⠃⠁⠴ ⠗⠭⠊ ⠱⠏ | 0.6667 | 1 | 0 |
| ⠏⠥ ⠱⠵⠁⠴ ⠚⠁⠆ ⠗⠁ | 0.6667 | 1 | 0 |

TABLE XII
THE N-GRAM ANALYSIS OF IBM 2 IS LARGER THAN THAT OF IBM 1 IN MYANMAR BRAILLE

| n-gram | match | IBM 1 | IBM 2 |
|---|---|---|---|
| ⠅⠔⠧⠄ | 0.2500 | 0 | 2 |
| ⠫⠑⠏⠤⠏⠞⠤⠞⠊ ⠧⠁⠫⠄ | 0.2500 | 0 | 2 |
| ⠏⠔⠧⠄⠆ ⠅ ⠞⠊⠑⠆ | 0.3333 | 0 | 1 |
| ⠗⠝⠄ ⠼⠁⠓⠓⠊ ⠨⠑ ⠝⠽⠎⠄ | 0.3333 | 0 | 1 |

### D. Sentence Example Analysis for Myanmar to Braille

For the translation of Myanmar to Braille, we also compared the translation output of IBM Model 1 and 2. Comparing the translation output error patterns of Myanmar to Braille is similar to translating Braille into Myanmar. The most frequent errors from the comparing results of sentence examples are shown in Table XIII to Table XVI.

TABLE XIII
INCORRECT TRANSLATION ERROR

| | Output | Sent-BLEU |
|---|---|---|
| Ref | [illegible] | |
| | ("Lion, Remember, Groan, Living Things." in English) | |
| IBM 1 | [illegible] | 73.4889 |
| IBM 2 | [illegible] | 100.0000 |

TABLE XIV
CONJUNCT CONSONANT WORDS ERROR

| | Output | Sent-BLEU |
|---|---|---|
| Ref | [illegible] | |
| | ("We also observed in Lacquerware Technology College." in English) | |
| IBM 1 | [illegible] | 86.664 |
| IBM 2 | [illegible] | 100.000 |

TABLE XV
UNTRANSLATED ERROR

| | Output | Sent-BLEU |
|---|---|---|
| Ref | [illegible] | |
| | ("Ko Lu Aye has been poisoned by the snake." in English) | |
| IBM 1 | [illegible] မွန် [illegible] | 65.8037 |
| IBM 2 | [illegible] မွန် [illegible] | 65.8037 |

TABLE XVI
NUMBER ERROR

| | Output | Sent-BLEU |
|---|---|---|
| Ref | [illegible] | |
| | ("4 kya. = A building which holds 256 tin paddy grain." in English) | |
| IBM 1 | [illegible] ၂၅၆ [illegible] | 81.5355 |
| IBM 2 | [illegible] ၂၅၆ [illegible] | 81.5355 |

Among the above tables, in Table XIII, IBM model 1 translates the reference word "[illegible]"("Groan" in English) into "[illegible]"("nyaee nyaee" in English). Therefore, the sentence accuracy of IBM model 1 is 73.4889. IBM model 2 can be translated correctly, so its sentence BLEU is better than IBM model 1. In Table XIV, IBM model 1 translates the numerical numbers "[illegible]" ("29999" in English) instead of the referencing conjunct consonant word "[illegible]" ("Technology" in English). Therefore, in Myanmar to Braille translation, IBM model 1 cannot translate some conjunct consonants well as in the translation from Braille to Myanmar. Table XV shows both IBM Model 1 and 2 came out as Myanmar text "မွန်" instead of braille script "[illegible]". From Myanmar to Braille translation, numerical translation error is shown in Table XVI.

After doing analysis of sentence example pairs of each model in detail, we found that the most common errors are confusion errors, and numeric errors. In confusion errors, "(" ==> ")" and ")" ==> "(" appeared in the translation of Braille to Myanmar because the script of braille for both "(" and ")" are the same. Some numerical errors occur in both directions of translation. Here, the numeric pairs of "၃၆၀၀" ==> "[illegible]" and "[illegible]" ==> "၂၅၆" are occurred because the model cannot translate the target output so that the model generates the input text. Both IBM Model 1 and 2 cannot fully convert the numbers. This type of confusion can be reduced by enhancing the proposed parallel corpus and model.

## VII. CONCLUSION

This paper contributes the first evaluation of the statistical machine translation techniques between Braille (Mu-Thit) and Myanmar text. We assumed that each Braille word is the translation of exactly one Myanmar word and thus the study was carried out based on the well known IBM Model 1 and 2. To evaluate Braille and Myanmar machine translation in both directions, we used 10,262 sentences from Myanmar Basic Education textbooks. According to the BLEU score, RIBES score, WER score and compare-mt results, Model 2 achieved slightly better results for Myanmar text to Braille (Mu-Thit) conversion and vice versa. After analyzing the compare-mt results, we detected bracket errors and numerical errors. Therefore, we used regular expressions (RE) to solve the bracket error through the post-editing process. As a result, BLEU score of Model 1 increased from 98.70 to 99.24 and Model 2 increased from 98.77 to 99.32 and the WER score was also better in Braille to Burmese translation. However, there is still a problem of solving numerical errors. The parallel corpus can be extended to improve the translation performance between Braille and Myanmar text. Moreover, there is a plan to develop Myanmar Braille (Mu-Haung) parallel corpus. Although Grade (2) Myanmar Braille (Mu-Haung) looks harder to translate than Grade (1) Myanmar Braille (Mu-Thit), IBM Model 1 and 2 will be applied in the near future.

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