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ENHANCING PUNJABI-HINDI BRAILLE NEURAL MACHINE TRANSLATION VIA SYNTACTIC ANALYSIS

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Abstract: This paper introduces a neural machine translation system designed for Punjabi to Bharati Braille. In response to the lack of an on-the-fly translation tool from Punjabi (Gurmukhi) to Bharati Braille, we crafted a system trained on a 6-lac parallel corpus. The training process included augmenting Punjabi text by translating name entities into Hindi. Comparative analysis against the baseline NMT system demonstrated a notable enhancement, as the syntax augmented NMT system achieved a score of 36.66, significantly outperforming the baseline's 26.34.

Keywords: Neural Machine Translation, Bharati Braille, Punjabi, Hindi, Syntax-based NMT

INTRODAUCTION

Blind people are vital members of our community, but they face significant barriers when it comes to accessing computers, the Internet, and high-quality educational software compared to those with full vision. Consequently, they have struggled to enhance their knowledge and make a substantial impact on economic, commercial, and educational initiatives in our community. To address this growing disparity and reverse this trend, we need to create an affordable system that empowers visually impaired individuals to communicate freely and effectively through the Internet or any other information infrastructure.

Traditionally, visually impaired individuals have relied on the Braille system for communication and connecting with the world. However, translation between different languages using the Braille coding system has been limited, challenging, and often one-way. Braille is not a language; it is a script. Bharti Braille is used for writing Indian languages in the Braille script. The National Institute of Visually Handicapped in India invented it. The Braille code system's widespread support in numerous communities can be attributed to its truthfulness and user-friendliness. Braille has been accepted across several languages, including Arabic, English, Hindi, Urdu, and many more. Bharti Braille is important for blind or deaf-blind people who speak Hindi. Bharti Braille makes the Hindi language usable for visually impaired people to write and read their language. The Braille Development Unit established notation systems for music, math, and science. Additionally, they generated Braille abbreviations and contractions for most of the country's official languages. Braille has had a major impact, offering a path to connect visually impaired people worldwide who had been separated by religious customs, caste prejudices, and social norms. Bharti Braille serves as a channel of social communication for blind or visually impaired people. It provides linguistic communication to blind individuals and is based on phonetics, making connecting to spoken or sound words easier. Bharti Braille is extending the education system for the visually impaired. Braille characters consist of a combination of a six-raised dot system with a 3*2 matrix, which is called the Braille cells. Braille text consists of contractions, punctuation, and letters.

A Braille cell adds six raised dots arranged in two columns, with every column having three dots. Numbers assign the dot location from one to six, resulting in sixty-four possible combinations, including the absence of dots to illustrate a word space. Braille was the first writing tool that used binary encoding. The Braille system consists of two parts:

1. A character encoding that mapped French alphabet characters to a tuple of six dots.
2. In a Braille cell, six-bit characters with raised dots are physically represented.

A main factor contributing to Braille's rise as the preferred medium of communication among blind or deaf-blind people is that it can be both written and read.

LITERATURE REVIEW

Blenkhorn et al. [1] have addressed the challenge of converting word-processed documents into Braille. They integrated a translation tool within Microsoft Word, enabling users to easily create formatted Braille documents. They have utilized a C-written Dynamic Link Library (DLL) for text-to-Braille conversion, ensuring reliable output, particularly for contracted Braille across various document types. The system featured a high-quality layout and acceptable processing speed, making it a valuable tool for Braille document production.

Wong et al. [2] have presented a software solution prototype tailored for the optical recognition of single-sided embossed Braille documents, integrating image processing techniques and a neural network. This innovative system generated the unaltered Braille text document, ready for replication through an electronic embosser. The system attained exceptional accuracy, surpassing 99%, in recognizing individual letters and words, all while maintaining an average processing time of 32.6 seconds per page.

Shahbazkia et al. [3] have introduced the project's objectives, which have been subdivided into seven distinct tasks. These tasks encompass the identification of Braille points, the segmentation of specific images containing Braille text, subsequent processing, language parsing, keyboard construction, system integration, and the development of a user interface. The software developed demonstrates a high level of accuracy in translating the content presented on Braille sheets.

Al-Salman et al. [4] have designed an Arabic Braille bi-directional and bi-lingual translation/editor system that obviated the requirement for costly equipment. This system demonstrated adaptability for a comprehensive scope, contributing to communication inclusivity across diverse individuals, irrespective of their disabilities, economic means, linguistic variations, or geographic dispersion. When they evaluated the system, they achieved satisfactory results.

Zhang et al. [5] have focused on the task of text-to-Braille translation utilizing Field-Programmable Gate Arrays (FPGAs). In contrast to conventional software-based methods, their translator executes translations through dedicated hardware. To enhance translation speed, they leverage FPGAs with substantial programmable resources and have optimized an algorithm based on P. Blenkhorn's work to facilitate rapid translation. Their system demonstrates significantly improved throughput when compared to Blenkhorn's original algorithm, positioning it as an efficient and high-performance text-to-Braille translation solution.

Hassan et al. [6] have introduced the conversion of English characters into Braille using Neural Network technology. They implemented this approach with MATLAB programming, transforming scanned page images into 400-element columns, which represented a 20x20 grid for each character. The Neural Network's output was utilized to adhere to Braille rules and generate corresponding Braille characters, which were stored as 2x6 element matrices for each character. The Neural Network, meticulously designed and trained to recognize 63 characters through the back-propagation training algorithm, offered both speed and high accuracy in the conversion process.

T. Dasgupta et al. [7] have introduced an automated Dzongkha text-to-Braille forward transliteration system, with a specific focus on Dzongkha, Bhutan's national language. The primary objective was to provide cost-effective and efficient accessibility solutions for individuals with visual impairments. Moreover, the system addressed the scarcity of automatic Braille transliteration systems in languages like Dzongkha. Its configuration allowed the processing of Dzongkha text documents as input, employing defined transliteration rules to produce Braille output, promising substantial improvements in accessibility for the visually impaired.

A. Mousa et al. [8] have defined the enhancement of each phase, commencing with image acquisition and culminating in the final stage of Braille cell recognition. This systematic approach comprised sequential steps, including image acquisition, image pre-processing to mitigate noise, an adapted image segmentation process, feature extraction, and ultimately, character recognition. The meticulous refinement of various stages in the process contributes to the advancement of Braille document recognition technology.

Al-Salman et al. [9] have developed a Braille copier machine that can create Braille documents in several languages. This machine operates on a copier and a printing system, utilizing image processing techniques and optical recognition.

Saxena et al. [10] have described a real-time integrated solution of software and hardware to assist blind or visually impaired people. A Braille hand glove was developed to facilitate real-time communication, allowing for the sending and receiving of messages.

Park et al. [11] have described a method for automatically translating scanned images from books into digital Braille books. They integrated the identification of characters and recognized images in print books, enabling the automatic translation of images into text. This method minimizes the cost and time required for generating print books into Braille, and it also provides reading materials for blind people.

Shimomura et al. [12] have described a translation system for converting Japanese into Braille script. They used MeCab, a morphological analysis engine programmed in C and Python, to translate Japanese into Braille code. TensorFlow was used as a neural network library, and a Neural Machine Translation system (NMT) was used to convert Japanese into Braille script.

Apu et al. [13] have proposed a user-friendly Braille system. They presented the working principle, design, and implementation of a Braille translating system. This device converted voice and text into Braille for visually impaired people. The device works for several languages and performs translation based on voice and text commands given by the end user.

Alufaisan et al. [14] have designed an application that recognized Arabic Braille numerals and translated them into plain text using a Convolutional Neural Network (CNN) based on a residual network. This system also provided speech support for the created text.

Yoo and Baek [15] have implemented a Braille module and display devices for text translation for blind individuals. To store documents as images on the device, they utilized a Raspberry Pi camera. Characters were extracted from the images and translated into Braille. The converted Braille information was processed to produce Braille cells. The proposed device was highly portable and could be created using 3D printing.

PROPOSED METHODOLOGY

For the conversion of Punjabi text to Hindi Braille, we utilized a dataset of 6 lac sentences from articles on culture, tourism, and art. The collected corpus was employed to grasp various syntactic structures inherent in Punjabi, driven by the goal of comprehensively capturing the language's nuances. Table 1 provides a detailed list of the sentences studied in this research.

Table 1: Sentences which were used in the Corpus.

S. No.	Construct
1	Simple Sentence
2	Infinitive Sentence
3	Gerund Sentence
4	Participle Sentence
5	Appositional Sentence
6	Initial Adverb
7	Coordinate Sentence
8	Copula Sentence
9	Wh-Structure

10	Relative Clause Sentence
11	Discourse Sentence

After the corpus collection was finished, text preprocessing was carried out. Initially, the text was tokenized, followed by POS tagging performed on the Punjabi corpus. Named entities were identified and extracted from the POS-tagged corpora. The specific types of named entities that held our particular interest included names of persons or individuals, locations or places, and organizations or institutions. Within this context, the names of individuals and locations required transliteration, entailing a transition from Gurmukhi script to Devanagari. Some organizations necessitated phrase translation, while others required transliteration. As a result, we developed a transliteration system based on phoneme extraction to transform Gurmukhi text into Hindi. Additionally, we constructed a translation sub-system, utilizing a rule-based module, to translate Punjabi named entities into Hindi. This is illustrated in the example sentence in table 2. The sentence "ਸਾਹਿਲ ਨੇ ਇੰਡੀਅਨ ਇੰਸਟੀਟਯੂਟ ਆਫ ਮੈਨੇਜਮੈਂਟ ਅਹਮਦਾਬਾਦ ਜਾਣ ਲਈ ਜਵਾਹਰ ਲਾਲ ਨੇਹਰੂ ਮਾਰਗ ਤੇ ਜਯਪੁਰ ਤੋਂ ਅਹਮਦਾਬਾਦ ਲਈ ਇੰਡਿਗੋ ਦੀ ਟਿਕਟ ਬੁੱਕ ਕਰਵਾ ਲਈ|" Initially, POS tagging was performed. In this context, we held a particular interest in NNPs (Proper Nouns) since our NER module examined them and classified the desired named entities. Thus, "ਸਾਹਿਲ" was recognized as person name; "ਇੰਡੀਅਨ ਇੰਸਟੀਟਯੂਟ ਆਫ ਮੈਨੇਜਮੈਂਟ", "ਇੰਡਿਗੋ" were recognized as organization names and "ਜਵਾਹਰ ਲਾਲ ਨੇਹਰੂ ਮਾਰਗ", "ਅਹਮਦਾਬਾਦ"," ਜਯਪੁਰ" were recognized as location names. Subsequently, they were translated as per the requirement. Ultimately, these were substituted within the source sentence, resulting in a structure that resembled the following, "साहिल ਨੇ भारतीय प्रबंधन संस्थान अहमदाबाद ਜਾਣ ਲਈ जवाहर लाल नेहरू मार्ग ਤੇ जयपुर ਤੋਂ अहमदाबाद ਲਈ इंडिगो ਦੀ ਟਿਕਟ ਬੁੱਕ ਕਰਵਾ ਲਈ।" The working of the name entity translation/transliteration process is depicted in Figure 1.

Table 2: Corpus Augmentation Process

Source Sentence	ਸਾਹਿਲ ਨੇ ਇੰਡੀਅਨ ਇੰਸਟੀਟਯੂਟ ਆਫ ਮੈਨੇਜਮੈਂਟ ਅਹਮਦਾਬਾਦ ਜਾਣ ਲਈ ਜਵਾਹਰ ਲਾਲ ਨੇਹਰੂ ਮਾਰਗ ਤੇ ਜਯਪੁਰ ਤੋਂ ਅਹਮਦਾਬਾਦ ਲਈ ਇੰਡਿਗੋ ਦੀ ਟਿਕਟ ਬੁੱਕ ਕਰਵਾ ਲਈ|
POS Tagging	ਸਾਹਿਲ_NNP ਨੇ_PSP ਇੰਡੀਅਨ_NNP ਇੰਸਟੀਚਿਊਟ_NNP ਆਫ_PSP ਮੈਨੇਜਮੈਂਟ_NNP ਅਹਮਦਾਬਾਦ_NNP ਜਾਣ_VM ਲਈ_VAUX ਜਵਾਹਰ_NNP ਲਾਲ_NNP ਨੇਹਰੂ_NNP ਮਾਰਗ_NNP ਤੇ_PSP ਜਯਪੁਰ_NNP ਤੋਂ_PSP ਅਹਮਦਾਬਾਦ_NNP ਲਈ_PSP ਇੰਡਿਗੋ_NNP ਦੀ_PSP ਟਿਕਟ_NN ਬੁੱਕ_VM ਕਰਵਾ_VAUX ਲਈ_VAUX ।_PUNC
Name Entity Recognition	ਸਾਹਿਲ_B-PER ਨੇ_O ਇੰਡੀਅਨ_B-ORG ਇੰਸਟੀਚਿਊਟ_I-ORG ਆਫ_I-ORG ਮੈਨੇਜਮੈਂਟ_I-ORG ਅਹਮਦਾਬਾਦ_B-LOC ਜਾਣ_O ਲਈ_O ਜਵਾਹਰ_B-LOC ਲਾਲ_I-LOC ਨੇਹਰੂ_I-LOC ਮਾਰਗ _I-LOC ਤੇ_PSP ਜਯਪੁਰ_B-LOC ਤੋਂ_O ਅਹਮਦਾਬਾਦ_B-LOC ਲਈ_O ਇੰਡਿਗੋ_B-ORG ਦੀ_PSP ਟਿਕਟ_O ਬੁੱਕ_O ਕਰਵਾ_O ਲਈ_O ।_O
Augmented Source Sentence	साहिल ਨੇ भारतीय प्रबंधन संस्थान अहमदाबाद ਜਾਣ ਲਈ जवाहर लाल नेहरू मार्ग ਤੇ जयपुर ਤੋਂ अहमदाबाद ਲਈ इंडिगो ਦੀ ਟਿਕਟ ਬੁੱਕ ਕਰਵਾ ਲਈ।

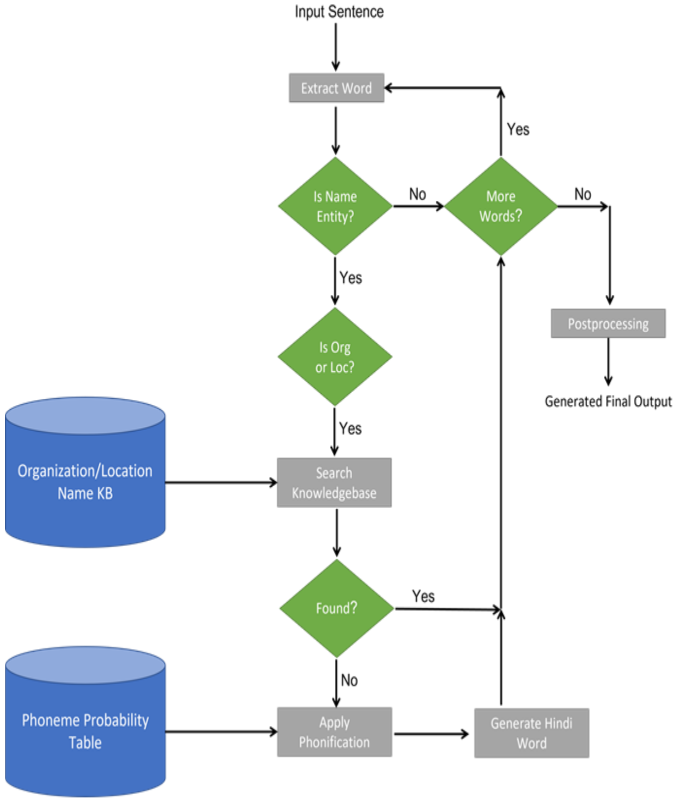

Figure 1: Name Entity Translation Subsystem

After corpus transformation (Figure 2), BPE encoding was applied to Punjabi and Hindi sources for NMT system training. Module added for NMT Hindi to Hindi Braille translation. A module was established for NMT to Hindi Braille translation. We built a Hindi to Bharati Braille system involving text preprocessing and phoneme extraction. Phonemes mapped to Bharati Braille through a knowledge base. For disambiguation, a bi-directional LSTM system was used, with FastText based Hindi phoneme-to-word embeddings. The entire dataset of 6 lac Hindi sentences was transformed into Bharati Braille using the developed knowledge base. Manual ambiguity resolution improved the phonified corpus for bi-LSTM training. The bi-LSTM handled ambiguity, integrating Braille characters into the workflow for Hindi phoneme conversion into Bharati Braille. The working of this subsystem is shown in figure 3. The comprehensive NMT workflow, including augmentation, is shown in Figure 4. In addition, a baseline NMT system was trained, utilizing only byte pair encoding for training. In the Baseline system Preprocessed Punjabi to Neural Translation to Hindi and Hindi Braille. The workflow of this baseline system is shown in Figure 5.

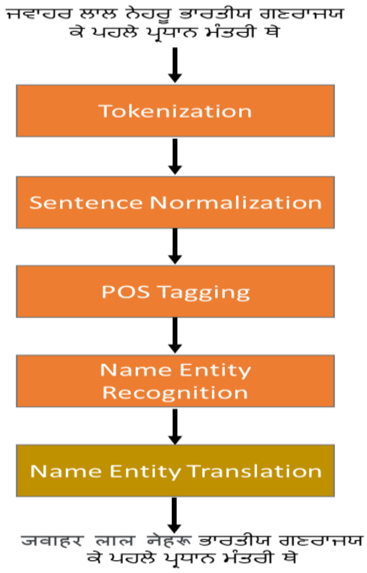

FIGURE 2: CORPUS AUGMENTATION PROCESS

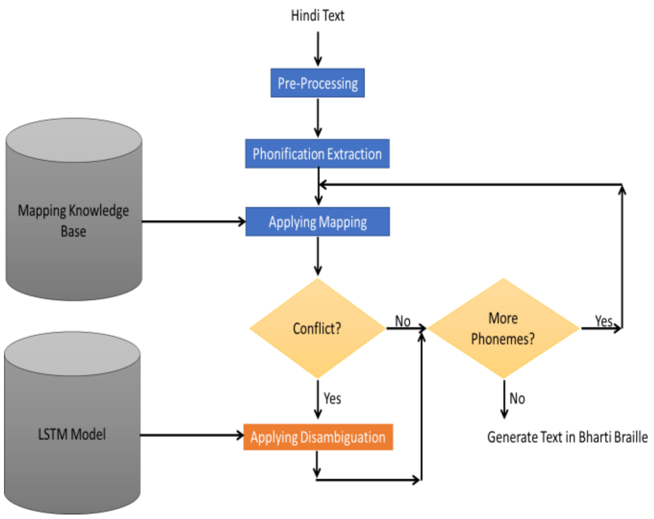

Figure 3: Hindi to Bharti Braille Translation Subsystem

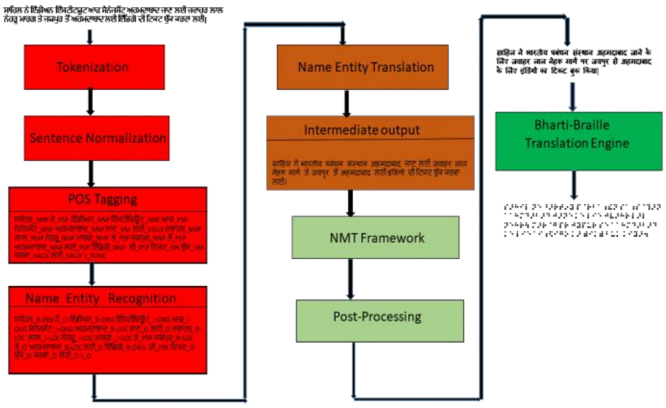

Figure 4: Workflow of Augmented NMT system

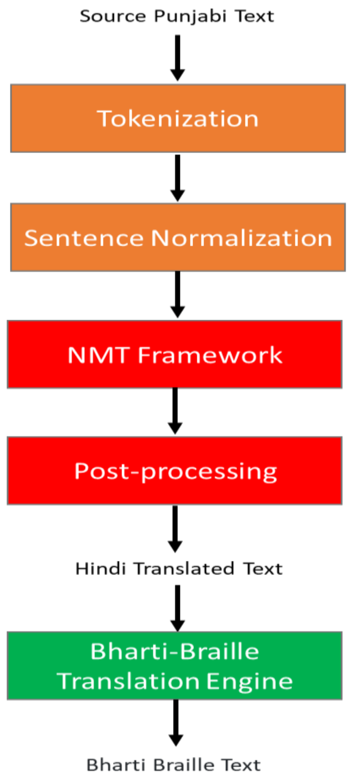

Figure 5: Workflow of Baseline NMT system

RESULTS

The machine translation system underwent a 2000-sentence test, evaluating results with the BLEU metric [16] and comparing them to the baseline system. BLEU, short for Bilingual Evaluation Understudy, assesses machine-generated translation quality in NLP. Proposed by Kishore Papineni et al. in 2002, it measures translation adequacy and fluency through n-gram precision (1, 2, 3, 4), using a brevity penalty to compensate for recall absence. The final score is a weighted geometric mean of n-gram scores, calculated as a division of MT output length and reference-length, or 1, whichever is lower.

$$\mathrm{BLEU} = \min\left(1, \frac{\text{MT output} - \text{length}}{\text{reference} - \text{length}}\right) \times \exp\left(\sum_{n=1}^{N} w_n \log(p_n)\right)$$

The baseline system faced challenges in translating named entities, resulting in a BLEU score of 26.34. Notably, syntax-based NMT exhibited significant improvement, scoring 36.66 (Table 3).

Table 3: Machine Translation Evaluation

NMT System	BLEU Score
Baseline System	26.34
Syntax Augmented NMT System	36.66

CONCLUSION

This paper outlines the creation of a neural machine translation system for Punjabi-Hindi Braille using 6 lac sentences. Enhancements, including a name entity translation sub-module, resulted in improved performance, reflected in BLEU scores of 26.34 (baseline) and 36.66 (augmented

NMT). Future plans involve corpus expansion, refining the name entity module, exploring alternative approaches, and integrating pre-trained BERT models to enhance translation accuracy.

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