

# Efficacy of ByT5 in Multilingual Translation of Biblical Texts for Underrepresented Languages

Corinne Aars<sup>†</sup> Lauren Adams<sup>†</sup> Xiaokan Tian<sup>†</sup> Zhaoyu Wang<sup>†</sup> Colton Wismer<sup>†</sup>  
Jason Wu<sup>†</sup> Pablo Rivas\* Korn Sooksatra Matthew Fendt

Department of Computer Science Baylor University

<sup>†</sup>Equal Contribution \*Correspondence: Pablo\_Rivas@Baylor.edu

## Abstract

This study presents the development and evaluation of a ByT5-based multilingual translation model tailored for translating the Bible into underrepresented languages. Utilizing the comprehensive Johns Hopkins University Bible Corpus, we trained the model to capture the intricate nuances of character-based and morphologically rich languages. Our results, measured by the BLEU score and supplemented with sample translations, suggest the model can improve accessibility to sacred texts. It effectively handles the distinctive biblical lexicon and structure, thus bridging the linguistic divide. The study also discusses the model’s limitations and suggests pathways for future enhancements, focusing on expanding access to sacred literature across linguistic boundaries.

## 1 Introduction

This study aims to use an advanced language model to make the translation of sacred texts, like the Bible, into less commonly spoken languages more efficient and quicker. The Bible’s structured format, with its division into books, chapters, and verses, allows for a wide variety of uses and highlights its rich foundational vocabulary. Using this extensive corpus, we trained a multilingual translation model to produce translations of Bible verses for languages that lack representation (Peters et al., 2018).

At present, translating religious texts into less commonly spoken languages is a lengthy and complex process. Finding a translator with proficiency in both the source and target languages can be challenging. Often, this translator is the primary person working on the translation, which can take a considerable amount of time to complete even a first draft. The subsequent process of refining this draft can extend over many years, delaying the availability of these important texts in the native languages of various communities. Our model aims to com-

plement rather than replace the traditional human translation process by making it more streamlined.

This research leverages the ByT5 multilingual translation model, trained on the John Hopkins University Bible Corpus (Xue et al., 2022; McCarthy et al., 2020), to facilitate the translation of Bible verses into several underrepresented languages. The ByT5 model is celebrated for its ability to produce high-quality text in numerous languages (Raffel et al., 2020), offering a robust solution to the challenges of translating sacred texts into languages with few resources. Our innovative method seeks to mitigate the issues inherent in conventional translation practices, such as the lack of available skilled translators and long project timelines. By employing the ByT5 model, we aim to enhance the speed and precision of Bible translations for languages with scant resources and expertise. Integrating advanced technology with linguistic diversity, we aspire to broaden the accessibility and cultural preservation of sacred texts, thereby enriching the cultural and linguistic fabric of religious literature for communities speaking underrepresented languages.

## 2 Background

ByT5 is an extension of the T5 model, which itself is a language model recognized for its effectiveness and was developed by Google Research (Raffel et al., 2020). ByT5 improves upon T5 by adopting byte-level tokenization, which enhances its proficiency with character-based languages such as Chinese and Japanese.

The tokenization at the byte level allows ByT5 to handle scripts that are character-intensive and may not exhibit clear word boundaries, or which utilize characters more extensively than words. This feature makes ByT5 particularly adept at interpreting the intricacies of such languages (Xue et al., 2022).

For languages characterized by rich morphol-

ogy, where words can have various inflections and derivations, ByT5’s tokenizer has shown increased accuracy, capturing morphological variations more precisely (Fujii et al., 2023). These capabilities are beneficial for translation, summarization, and question-answering tasks. By tokenizing at the character level, ByT5 demonstrates enhanced generalizability across languages, which is particularly useful for languages with sparse training data. This adaptability has been documented to improve multilingual model performance. Furthermore, byte-level tokenization generally results in a smaller vocabulary than word-level tokenization, which contributes to more efficient model training and inference, as well as reduced memory and computational needs.

The John Hopkins University Bible Corpus was selected to train our model. This corpus is notable for its size and organization, comprising over 4000 versions of the Bible across more than 1600 languages (McCarthy et al., 2020). Its parallel structure across translations makes it advantageous for machine learning applications. Other corpora fall short in these particular aspects (Sierra et al., 2024).

This corpus is especially marked by its linguistic diversity, offering both full and partial texts in a myriad of languages, some of which are significantly underrepresented with only a single book of the Bible translated. Such disparity highlights the necessity of our work.

The construction of this corpus involved extensive web scraping and merging with existing corpora. It underwent a thorough cleaning and alignment process to ensure the texts were structured verse-parallel, which is ideal for training machine learning models.

### 3 Methodology

This section delineates the systematic approach employed for training our model and tuning its parameters.

#### 3.1 Model Training

The ByT5 model was selected for its proficiency in byte-level tokenization, which is critical for discerning subtle linguistic differences in underrepresented languages (Wang et al., 2020). Our primary dataset, derived from the Johns Hopkins Bible Corpus, encompasses various linguistic variations, furnishing our models with an extensive linguistic foundation for learning (McCarthy et al., 2020).

#### 3.2 Parameter Tuning

We determined the ByT5 training hyperparameters through an iterative experimental protocol (Ebrahimi and Kann, 2021). Adjustments were made to the learning rate, early stop criteria, patience, and batch size, to distill an optimal parameter set for our specific translation endeavor. Our configuration included a learning rate of 0.0002, a scheduler factor of 0.5, patience of 10, a batch size of 48, and a maximum of 500 epochs with early stopping that usually ceases around epoch 43. Our dataset encompassed 3 million data samples, i.e., pairs of source-target translations.

By coupling a linguistically diverse corpus with meticulous parameter optimization, we aim to bolster ByT5’s translation efficacy for languages that are often overlooked in machine translation (Costajussà et al., 2022).

## 4 Results and Discussion

Moving from our methodology to its outcomes, we evaluate the translation quality of our ByT5-based multilingual translation model.

#### 4.1 Translation Quality

We utilized the BLEU (Bilingual Evaluation Understudy) score, a standard metric in machine translation evaluation, to assess our model’s accuracy by comparing its outputs with human translations. Our model achieved a BLEU score of 0.27, which signals its potential in handling translations, particularly in the domain of underrepresented languages.

The score achieved not only sheds light on the model’s capabilities but also underscores the intricate nature of machine translation tasks. Although the BLEU score is a valuable metric, it does not capture all aspects of language translation, such as the true linguistic fidelity and fluency that are crucial in the context of less common languages, which often lack established benchmarks.

For a more comprehensive illustration of our model’s performance across various language pairs, we have compiled a series of translation examples in Table 1.

#### 4.2 Analysis

The outcomes presented above offer a glimpse into a promising avenue for employing NLP models in assisting with the translation of sacred texts. Our model’s particular strength lies in its fine-tuning to the specificities of biblical language and style.

Language	Target text	Translated text
English	Jesus heard that John was put in prison , so he went back to Galilee.	When Jesus heard that John had been arrested, he went back to Galilee.
	And He warned them to tell no one about Him.	And he charged them that they should tell no man of him.
	Today your Savior was born in David’s town. He is Christ, the Lord.	for today in the city of David a Saviour was born to you, which is Christ the Lord.
Spanish	porque decía : « Si toco tan sólo su manto , seré salva . »	Porque decía: Si tocare tan solamente su vestido, seré salva.
	y diciendo : « Tú , el que derribas el Templo y en tres días lo reedificas , sálvate a ti mismo . Si eres Hijo de Dios , desciende de la cruz . »	y diciendo: Tú, el que derribas el templo, y en tres días lo reedificas, sálvate a ti mismo. Si eres Hijo de Dios, desciende de la cruz.
	Jesús salió llevando su cruz , para ir al llamado « Lugar de la Calavera » ( que en hebreo se llama Gólgota ) .	Y llevando su cruz, salió al lugar que se dice de la Calavera, y en hebreo Gólgota;
Marathi	म्हणून ज्याच्याविषयी तो बोलतो तो कोण आहे हे आम्हास सांग, असे शिमोन पेत्राने त्यास खुणावून म्हटले.	शिमोन पेत्राने त्या शिष्याला खुणावले आणि म्हणाला, “ ज्याच्याविषयी तो बोलतो तो कोण आहे हे विचार.
	आणि तेथे काही मेंढपाळ रात्रीच्या वेळी शेतामध्ये राहून आपले कळप राखीत होते.	आणि तेथे काही मेंढपाळ रात्रीच्या वेळी शेतामध्ये राहून आपले कळप राखीत होते.
	तर आता काय करावे? तुम्ही आला आहात हे ते खातरीपूर्वक ऐकतील.	“ मग आता काय केले पाहिजे? तू येथे आला आहेस हे त्यांना नक्की कळेल.
Chinese	说完,他又告诉他们:“我们的朋友拉撒路睡着了,我去叫醒他。”	说完,他又告诉他们:“我们的朋友拉撒路睡着了,我去叫醒他。”
	当他发现,这么做很讨犹太人时,便索性又把彼得也抓了起来。(当时正值逾越节期间)	当他发现,这么做很讨犹太人时,便索性又把彼得也抓了起来。(当时正值逾越节期间)
	因为我有五个兄弟,让拉撒路告诫他们,以便将来他们不会到这个受尽折磨的地方来。’	因为我有五个兄弟,让拉撒路告诫他们,以便将来他们不会到这个受尽折磨的地方来。’

Table 1: Comparative Analysis of ByT5 Model Translations with Target Texts in Multiple Languages. In this example, Marathi is an underrepresented language. Please see Table 2 in the Appendix for more samples.

Contrary to broader language models like Google Translate, our specialized training on the biblical corpus allows our system to adeptly handle the unique linguistic features of widely spoken and underrepresented languages alike.

The application of NLP to support the translation of significant texts holds promise for broader cultural and linguistic access. Such improvements in translation technology could hasten the delivery of these important works to communities with underrepresented languages. Our findings demonstrate the potential and scalability of language models to translate a vast spectrum of sacred texts. This model shows the capacity of NLP to bridge linguistic and cultural divides. As NLP technologies advance, they herald new possibilities for promoting linguistic diversity and spreading knowledge.

## 5 Conclusions

The investigation into the ByT5 model’s ability to translate sacred texts into underrepresented languages has demonstrated promising results. Our research revealed that the model, trained on the Johns Hopkins University Bible Corpus, not only can han-

dle the complexities inherent to diverse linguistic structures but also shows potential in improving access to significant cultural literature. Despite the challenges underscored by the BLEU scores, which may not fully capture linguistic nuances, the model’s translations remained reasonably accurate and faithful to the source texts.

Future research could explore refining the model’s parameters further to enhance translation quality, especially for languages with limited linguistic data. Additionally, the integration of ByT5 with other NLP tools may yield better comprehension of context and idiomatic expressions. The overarching aim of our work—to facilitate the sharing of sacred texts across cultural and linguistic barriers—has been substantiated by the findings, suggesting that advanced NLP models can indeed be a catalyst for increased inclusivity in the realm of sacred literature. The scalability of our approach also opens avenues for extending this work to other significant texts, potentially enriching the cultural and educational resources available to underrepresented language speakers worldwide.

## Acknowledgments

Part of this work was funded by the National Science Foundation under grants CNS-2210091, CHE-1905043, and CNS-2136961.

## References

- Marta R Costa-jussà, James Cross, Onur Çelebi, Maha Elbayad, Kenneth Heafield, Kevin Heffernan, Elahe Kalbassi, Janice Lam, Daniel Licht, Jean Maillard, et al. 2022. No language left behind: Scaling human-centered machine translation. *arXiv preprint arXiv:2207.04672*.
- Abteen Ebrahimi and Katharina Kann. 2021. [How to adapt your pretrained multilingual model to 1600 languages](#). In *Proceedings of the 59th Annual Meeting of the Association for Computational Linguistics and the 11th International Joint Conference on Natural Language Processing (Volume 1: Long Papers)*, pages 4555–4567, Online. Association for Computational Linguistics.
- Takuro Fujii, Koki Shibata, Atsuki Yamaguchi, Terufumi Morishita, and Yasuhiro Sogawa. 2023. How do different tokenizers perform on downstream tasks in scriptio continua languages?: A case study in japanese. *arXiv preprint arXiv:2306.09572*.
- Arya D. McCarthy, Rachel Wicks, Dylan Lewis, Aaron Mueller, Winston Wu, Oliver Adams, Garrett Nicolai, Matt Post, and David Yarowsky. 2020. [The Johns Hopkins University Bible corpus: 1600+ tongues for typological exploration](#). In *Proceedings of the Twelfth Language Resources and Evaluation Conference*, pages 2884–2892, Marseille, France. European Language Resources Association.
- Matthew E. Peters, Mark Neumann, Mohit Iyyer, Matt Gardner, Christopher Clark, Kenton Lee, and Luke Zettlemoyer. 2018. [Deep contextualized word representations](#). In *Proceedings of the 2018 Conference of the North American Chapter of the Association for Computational Linguistics: Human Language Technologies, Volume 1 (Long Papers)*, pages 2227–2237, New Orleans, Louisiana. Association for Computational Linguistics.
- Colin Raffel, Noam Shazeer, Adam Roberts, Katherine Lee, Sharan Narang, Michael Matena, Yanqi Zhou, Wei Li, and Peter J. Liu. 2020. [Exploring the limits of transfer learning with a unified text-to-text transformer](#). *Journal of Machine Learning Research*, 21(140):1–67.
- Gerardo Sierra, Gemma Bel-Enguix, Ameyali Díaz-Velasco, Natalia Guerrero-Cerón, and Núria Bel. 2024. [An aligned corpus of spanish bibles](#). *Language Resources and Evaluation*.
- Changhan Wang, Kyunghyun Cho, and Jiatao Gu. 2020. Neural machine translation with byte-level subwords. In *Proceedings of the AAAI conference on artificial intelligence*, volume 34, pages 9154–9160.

Linting Xue, Aditya Barua, Noah Constant, Rami Al-Rfou, Sharan Narang, Mihir Kale, Adam Roberts, and Colin Raffel. 2022. ByT5: Towards a token-free future with pre-trained byte-to-byte models. *Transactions of the Association for Computational Linguistics*, 10:291–306.

## A Appendix: Additional Sample Translations

This appendix features Table 2, which showcases the ByT5 model’s translation capabilities across several languages. Each entry includes the original target text followed by the translated text generated by the model. The juxtaposition illustrates the model’s proficiency in maintaining the semantic integrity of complex religious narratives, as well as its handling of diverse linguistic structures ranging from English and German to more character-centric languages like Chinese and Japanese. This comparative exhibit serves not only as a testament to the ByT5 model’s linguistic versatility but also as a valuable resource for future research and development in the field of machine translation of sacred texts.

Language	Target text	Translated text
English	Since that harbor was not a good place for the ship to stay for the winter , most of the men decided that the ship should leave . They hoped we could go to Phoenix and stay there for the winter . Phoenix , a city on the island of Crete , had a harbor which faced southwest and northwest .	And because the harbor was not commodious to winter in, the more part decided to put to sea from there, if somehow they could reach Phoenix, and winter there; which is an harbor of Crete, facing southwest and northwest, and spend the winter there.
	And when they had entered, they went up to the upper room, where they were staying, Peter and John and James and Andrew, Philip and Thomas, Bartholomew and Matthew, James the son of Alphaeus and Simon the Zealot and Judas the son of James.	And when they were come in, they went up into the upper chamber, where they were abiding; both Peter and John and James and Andrew, Philip and Thomas, Bartholomew and Matthew, James the son of Alphaeus, and Simon the Zealot, and Judas the son of James.
German	Und diese Rede von ihm verbreitete sich in ganz Judäa und in die ganze Umgegend .	Und diese Rede über ihn erscholl in ganz Judäa und in alle umliegenden Länder.
	Es kamen auch Zöllner , um sich taufen zu lassen , und sagten zu ihm : " Meister , was sollen wir tun ? "	Es kamen aber auch Zöllner, daß sie sich taufen ließen, und sprachen zu ihm : Meister, was sollen denn wir tun?
France	Et ce qui est tombé entre des épines , ce sont ceux qui ayant ouï la parole , et s'en étant allés , sont étouffés par les soucis , par les richesses , et par les voluptés de cette vie , et ils ne rapportent point de fruit à maturité .	Et ce qui est tombé parmi les épines, ce sont ceux qui, ayant entendu la parole, et s'en étant allés, sont étouffés par les soucis, par les richesses et par les voluptés de cette vie, et ils ne portent point de fruit à maturité.
	Si donc , méchants comme vous l'êtes , vous savez donner de bonnes choses à vos enfants , à combien plus forte raison le Père céleste donnera-t-il le Saint-Esprit à ceux qui le lui demandent .	Si donc vous, qui êtes méchants, savez donner à vos enfants des choses bonnes, combien plus votre Père céleste donnera-t-il le Saint-Esprit à ceux qui le lui demandent?
Russian	но писал вам , братья , с некоторою смелостью , отчасти как бы в напоминание вам , по данной мне отБога благодати	Но я довольно смело писал вам о некоторых делах, которые мне хотелось бы, чтобы вы запомнили. Я сделал это, потому что даровано мне было по
	И в другом месте Писания говорится: «Они будут смотреть на Того, Которого пронзили»†.	И ещё в другом [ месте ] Писания говорится : воззрят на Того, Которого пронзили.
Japanese	だから、兄弟たちよ、この事を承知しておくがよい。すなわち、このイエスによる罪のゆるしの福音が、今やあなたがたに宣べ伝えられている。そして、モーセの律法では義とされることができなかったすべての事についても、	だから、兄弟たちよ、この事を承知しておくがよい。このことによる罪のゆるしの福音が、今あなたがたに宣べ伝えられている。そして、モーセの律法では義とされることがないので
	これらのことを話したのは、あなたがたがわたしによって平和を得るためである。あなたがたには世で苦難がある。しかし、勇気を出しなさい。わたしは既に世に勝っている。」	これらのことをあなたがたに話したのは、わたしにあって平安を得るためである。あなたがたは、この世ではなやみがある。しかし、勇気を出しなさい。わたしは世に勝っている。」

Table 2: Comparative Analysis of ByT5 Model Translations with Target Texts in Multiple Languages.