

Identifying Open Challenges in Language Identification

Rob van der Goot

IT University of Copenhagen

robv@itu.dk

Abstract

Automatic language identification is a core problem of many Natural Language Processing (NLP) pipelines. A wide variety of architectures and benchmarks have been proposed with often near-perfect performance. Although previous studies have focused on certain challenging setups (i.e. cross-domain, short inputs), a systematic comparison is missing. We propose a benchmark that allows us to test for the effect of input size, training data size, domain, number of languages, scripts, and language families on performance. We evaluate five popular models on this benchmark and identify which open challenges remain for this task as well as which architectures achieve robust performance. We find that cross-domain setups are the most challenging (although arguably most relevant), and that number of languages, variety in scripts, and variety in language families have only a small impact on performance. We also contribute practical takeaways: training with 1,000 instances per language and a maximum input length of 100 characters is enough for robust language identification. Based on our findings, we train an accurate (94.41%) multi-domain language identification model on 2,034 languages, for which we also provide an analysis of the remaining errors.¹

1 Introduction

Language identification is a crucial step for many Natural Language Processing (NLP) pipelines. It can for example be used to provide conditional information for multi-lingual models (Conneau and Lample, 2019), decide which model to use, to pre-filter raw data for training language models (Kreutzer et al., 2022), or even for filtering data to annotate. High performances have been obtained with numerous benchmarks and models, although previous work has also focused on specific

challenging dimensions, for example, social media data (Lui and Baldwin, 2014a), in cross-domain setups (Lui and Baldwin, 2011), or for short input texts (Tofrup et al., 2021).

To the best of our knowledge, evaluation of language identification has been fragmented and setups vary across many dimensions, including domains, datasets, metrics, number of languages, input size, amount of training data, number of scripts, and number of language families. In this paper, we will carefully compose a benchmark consisting of a variety of open sources, and we constrain our setup among several dimensions to identify open challenges in language identification and perform an in-depth robustness evaluation of common language identification models. We inspect the effect of size of input per instance, number of instances per language, number of supported languages, domain overlap, language family distance, and script overlap. We use a variety of types of popular language identification tools, which we re-train for all evaluations for a fair comparison. Our contributions are:

- We provide a dataset for language identification that allows for creating subsets that are stratified among a variety of dimensions.
- We evaluate five commonly used language identification models on a variety of benchmarks sampled from our main collection of datasets.
- We identify open problems for the task of language classification of text.
- We release a language classification model with the largest set of supported languages (2,034) to date, and analyze remaining errors.

2 Models

We focus on the most popular and best-performing methods for language identification and pick a com-

¹Code and best-performing models are available on: <https://bitbucket.org/robvanderlangid/problems>

monly used implementation for each method. For a more complete overview of architectures used for language identification, we refer to [Jauhiainen et al. \(2019\)](#). For all our experiments we train the models from scratch for a fair comparison. We ended up with the following categories and models:

N-gram overlap Character n-gram frequencies provide a footprint of a text, and have indeed for a long time been used successfully as features in machine-learning text classification problems. Note that character n-gram overlaps are more robust as compared to words n-grams, as for many languages it is unclear what the word boundaries are. We use the approach proposed by [Cavnar et al. \(1994\)](#) as implemented by [van Noord \(1997\)](#), named **Textcat**. In short, the model first builds profiles for languages by looking for the 400 most frequent 1-5 character n-grams, and then calculates the distance of this ranked list to a ranked list of 1-5 character n-grams of the target utterance. The input text will be classified to the most similar profile.

Naive Bayes A variety of machine learning algorithms, such as Naive Bayes (e.g. [Zampieri et al., 2014, 2015](#)), SVM (e.g. [Majliš, 2012](#)), and Logistic Regression (e.g. [Bhargava et al., 2015](#); [Camposampiero et al., 2022](#)) have successfully been used for the language identification task. Character n-grams are commonly used as robust input features. We choose a Naïve Bayes (**NB**) classifier since it has shown to perform well ([Brown, 2014](#)) and is computationally more efficient (especially with large amounts of classes). Initially, we used `langid.py`, a widely used standalone Python package for language identification. However, performance were unexpectedly poor, perhaps because of our conversion python3. Hence, we reimplemented a multinomial Naive Bayes with default settings of `scikit-learn` ([Pedregosa et al., 2011](#)) based on character n-grams for which we did a small hyperparameter search on a setup with 100 languages (and 100 instances of 100 characters). We ended up with 1-5 grams, binary feature representations (as opposed to counts or TF-IDF), and 100,000 maximum features.

This specific implementation uses Naïve Bayes with byte n-grams (1-4) as input features.

Static embeddings **FastText** ([Joulin et al., 2017](#)) is a popular toolkit for language identification. It uses a bag of character n-grams as input with a single hidden layer to obtain predictions. The orig-

inal fastText model for language identification has been trained on 176 languages (Wikipedia data), but follow-up work has shown strong performance in a variety of setups (e.g. [Burchell et al., 2023](#); [Kargaran et al., 2023a](#)). We follow the hyperparameter setup of [Burchell et al. \(2023\)](#) and [Kargaran et al. \(2023a\)](#), except the number of epochs (we use 10 instead of 2), because we use less data.

LSTM LSTMs ([Hochreiter and Schmidhuber, 1997](#); [Graves and Schmidhuber, 2005](#)) were first used for language identification by [Cazamias et al. \(2015\)](#). More recently, Bi-LSTM models have been shown to perform competitively, especially for short input texts ([Tofttrup et al., 2021](#)). As we could not find a good reference for generic hyperparameters, we did a small fine-tuning search detailed in [Appendix A](#).

Contextualized language models Just like for many other NLP tasks, transformer-based language models have shown promising results for language identification. For example, in the recent Discriminating Between Similar Languages (DSL-TL) shared task ([Aeppli et al., 2023](#)), the highest performances were obtained by language models. One downside of language models for this task is the constrained subword vocabulary, certain scripts, and languages that are underrepresented will be harder to classify, and in some cases with only unknown characters even impossible. We evaluated a range of multi-lingual language models on a subset of our data, and will do our main experiments with **Glott500** ([ImaniGooghari et al., 2023](#)), due to its superior performance (comparison to other language models is available in [Appendix C](#)). We did not experiment with generative language models, as previous work ([Robinson et al., 2023](#); [Chen et al., 2023](#)) has shown subpar performance while they are computationally expensive.

3 Data

3.1 Sources

We selected data sources based on the quality of the language labels, diversity in domains/languages and availability. We removed parts of datasets that had multiple domain labels, were taken from other datasets in the list, or were translated Wikipedia data. We limit our studies to mono-lingual utterances, as opposed to language identification on code-switched data ([Doğruöz et al., 2021](#); [Winata et al., 2023](#)). The data sources we list are all pub-

Dataset	langs	scripts	fams	domains
MIL-TALE	2,110	47	139	wiki, political, religious, grammar
UDHR	397	38	61	rights
OpenLID	139	25	16	literature, news, wiki, social, grammar, subtitles, spoken
MassiveSumm	77	24	13	news
TwitUser	59	20	13	social
UD	54	11	17	medical, news, academic, wiki, legal, nonfiction, learner-essays, fiction, social, grammar-examples, reviews, religious, spoken
Total	2,176/ 7,850	51/ 163	145/ 298	

Table 1: Dataset statistics. The languages counts (langs) are based on the ISO-639-3 standard, script counts on ISO 15924, and language families (fams) on Glottolog (Hammarström et al., 2023).

licly available and not tokenized. They are also not (consistently) sentence-segmented, so in some cases, the input is a sentence, and in other cases, they are paragraphs (or tweets in the case of Twitter). We removed all classes with less than 2,000 instances, so that we can have 1,000 instances for evaluation, and still have enough data left to train on. Further label cleaning is described in Appendix D. Dataset statistics are provided in Table 1.

MIL-TALE To the best of our knowledge, MIL-TALE (Brown, 2014) is the publicly available dataset with the widest language coverage. At the time of downloading (15-11-2023), it contained data for 2,221 languages from which 2,110 were left after our only keeping languages with more than 2,000 utterances. A vast majority of the data is of religious nature.

Universal Declaration of Human Rights A small (~90 lines) standardized text that is translated to many languages is the “Universal Declaration of Human Rights” (UDHR). We use this only as test data and scraped the most recent collection from <http://unicode.org/udhr/d/>. We used this dataset because of its distinct domain, and wide coverage of languages.

OpenLID Open-LID (Burchell et al., 2023) is a collection of already existing datasets (including MIL-TALE, which we already included, so we exclude the Open-LID version). We use the version of the dataset without sampling.

MassiveSumm Varab and Schluter (2021) automatically collected summarization data from the news domain with the clear desiderata of inclusivity and language variety. We use the original texts as input text (not the summaries). It should be

noted that the utterances in this dataset are quite long (they are paragraphs), but we usually use only the first 100 characters for our experiments.²

Twituser A smaller dataset, with a focus on a single domain, is created by (Lui and Baldwin, 2014b). They collect Twitter messages based on language identification on the set of their tweets. Once they are certain that a user is tweeting mainly monolingual, they sample a small amount (to avoid user bias) of each user. The size of this dataset is relatively small, but we include it because it can give us valuable insights into the performance of language classification on less standard (web) domains.

UD We include Universal Dependency treebanks from UD v2.12 (Zeman et al., 2023). This dataset is rich in domain varieties, and we expect the language labels to be mostly accurate³ since each dataset is manually annotated for syntax by speakers of the language. To ensure accurate domain information, we exclude all multi-domain treebanks.

3.2 Exploratory Data Analysis

We list basic dataset statistics in Table 1. These statistics highlight the variety of properties of the datasets, where some have a more distinctive domain (rights/social), others are rich in domain varieties (UD, OpenLID), and MIL-TALE for example has a much larger amount of languages covered. The total coverage of languages is now close to ~50%, as out of the ~7,000 languages that exist, only ~4,000 are estimated to have a “developed writing system”.⁴ For the scripts, we cover only

²Because we show that there is little effect of using longer inputs in Section 4.1

³We do not take into account the word level labels

⁴<https://web.archive.org/web/20230113104023/https://www.ethnologue.com/enterprise-faq/>

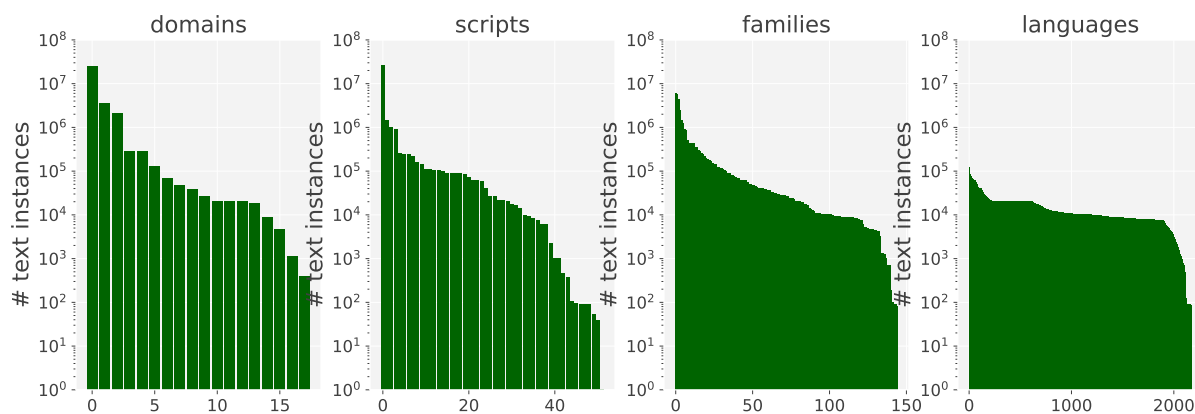


Figure 1: The number of text instances belonging to each category in our data among multiple dimensions.

about 1/3, and for language families the coverage is again $\sim 50\%$ (the 23 isolates in our data are not included in this count).

We also plot the number of datasets as well as utterances per domain, script, family, and language to get an overview of the amount of variety/information available across these dimensions. Figure 1 shows the distribution of text instances across different dimensions: domains, scripts, families, and languages. All of these have a similar shape, although for the dimensions with more labels, the largest set is smaller. They also show a long tail of low frequent labels (note that the y-axis is log-scale), though we did filter out the smallest sets.

4 Experiments

We carefully design our data splits for each of the dimensions that we will evaluate, hence we split this section into the different dimensions. We will start with data size, which includes the number of languages, amount of utterances per language, and length per utterance (Section 4.1). After this, we choose appropriate values of these dimensions and evaluate the other dimensions: language families (Section 4.2), scripts (Section 4.3), and domains (Section 4.4). Finally, we train a model on all our data and evaluate the effect of merging writing script with language labels (Section 4.5). For all our experiments we sample 1,000 utterances per language to use as test data⁵ and report the average scores over three seeds. For ease of interpretation and because our evaluation sets are always balanced we use accuracy for all our main evaluations

⁵how-many-languages-world-are-unwritten-0

⁵we do not tune any models, so we do not use a development split

(i.e. unless mentioned otherwise).

4.1 Amount of information

Setup We first vary the amount of information given to the model, we vary among three dimensions 1) a maximum of 10, 100, or 1,000 characters of each instance, which we choose to (very approximately) match, words, sentences and paragraphs (it should be noted that some of our data sources are sentence-split, so they are not much longer than 100 characters) 2) 10, 100, or 1,000 utterances per language 3) sets of 10, 100, or 1,000 languages. We use different samples of languages for each random seed. We do not control for language family, script, or domain here, so the data is multi-domain (but we pick one random domain and script per language). Note that we have thus trained a total of 81 models per architecture (3 character sizes * 3 utterance sizes * 3 amount of languages * 3 seeds) for this experiment.

Results Figure 2 shows all results for the different amounts of information among all dimensions. In general, performance is more dependent on the setup as opposed to the choice of the model. GLOT500 achieves robust performance amongst most settings; this is most likely due to the fact that it is the only pre-trained model (for other models there are no publicly massively multilingual pre-trained representations), and the only clear breakdown happens at 10 utterances or characters per language. It is clear that the other models are more dependent on the amount of information, they have much stronger gains when having more utterances per language. Having access to 100 characters performs on-par for 1,000 characters for most setups, showing that there is enough signal in lengths that approximate match sentences. Our results also

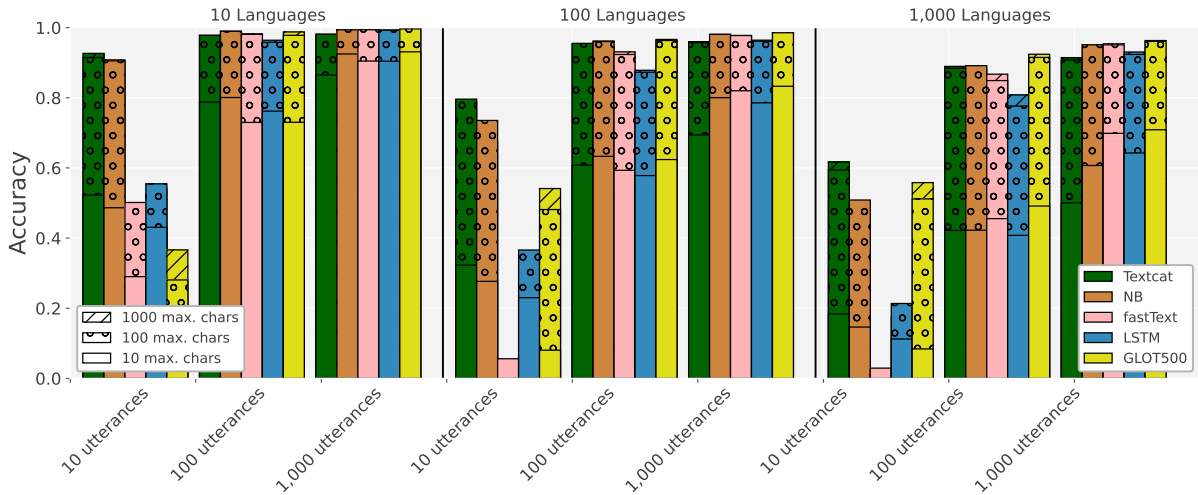
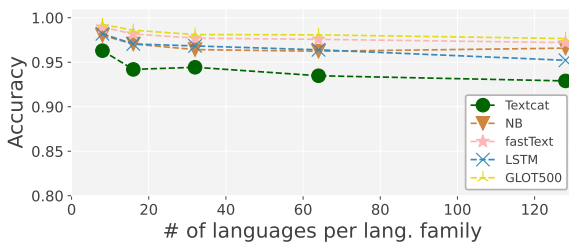
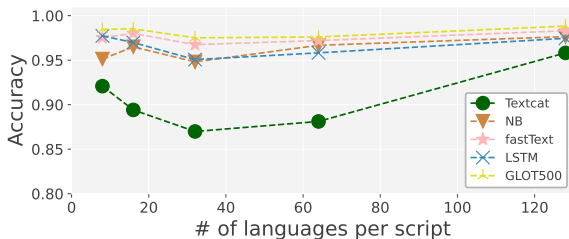


Figure 2: Comparison of all models when considering different amounts of information.



(a) Effect of number of language families in a sample of 128 languages.



(b) Effect of number of scripts in a sample of ~128 languages (note that it was impossible to sample this exact amount for the smaller numbers of scripts).

Figure 3: Performance with varying amounts of language families/scripts in a sample of ~128 languages. Concretely, this means that at the right of the figures, we have just a single language family or script, whereas on the left we have 8 languages for 16 language families/scripts.

show that 1,000 utterances with 100 characters lead to a very high performance across all numbers of languages, which has practical implications both for training time and requirements for low-resource languages. Standard deviation for all settings is reported in Appendix B and shows that the variance is mainly dependent on the setup, where setups with few languages or few characters per instance

have a larger variance.

4.2 Number of language families

Setup We evaluate the effect of the number of language families in a setup by sampling a preset number of languages for each language family, where we have a total of 128 languages. On one extreme, we can have a single language family with 128 languages, on the other extreme, we can have 16 language families with each 8 languages (note that 128 families with 1 language is not possible with our dataset, as we only have 51 language families). We hypothesized that classifying within a language family is more challenging, as the languages are more likely to be similar. Similar to our other settings, we run for three seeds, with different sets of languages (and language families).

Results The results (Figure 3a) show that there is a small negative effect when the number of languages within a language family increases for almost all models. Textcat and the LSTM show a slightly higher sensitivity to an increasing amount of languages within a family, but drops overall are marginal.

4.3 Number of scripts

Setup We follow a similar setup as for language families, but group the languages by their main script. It should be noted that it was not possible for the settings with 8 and 16 scripts per language to obtain 126 total languages, so here we were limited to respectively 72 and 64 languages.

Results The number of scripts (Figure 3b) has a slightly different trend compared to language fam-

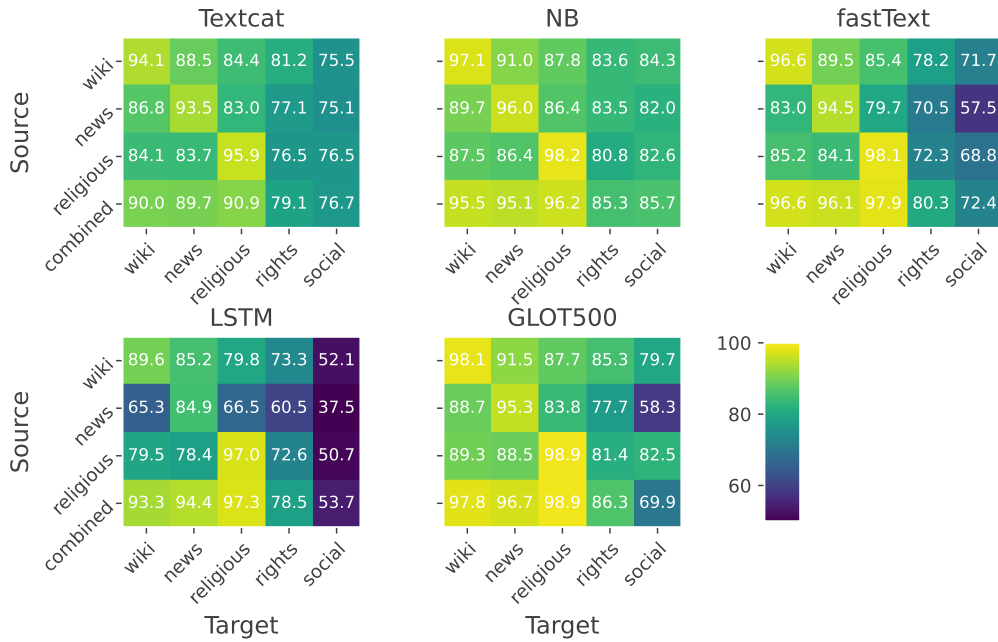


Figure 4: Accuracies in cross-domain setups (the diagonals are in-domain).

ily (Figure 3a), and has a larger effect on performance. There is a drop in performance when having 32 families per script, but when the number increases performance increases again. We hypothesize that this is due to the fact that the models can learn more accurate representations of their features due to a higher overlap. For example, there will be more overlap for character n-grams for fastText, and when there are more occurrences of a single feature, the model can learn a better representation for this feature.

4.4 Domain effect

Setup To evaluate the effect of domain transfer, we train single domain models on the largest three domains (to ensure a large number of languages and enough data), and evaluate the performance across these domains, as well as on the ‘rights’ and the ‘social’ domain. We also train a model on the three source domains jointly, to evaluate whether a multi-domain model is more robust against domain shift. The rights domain consists of the data from the Universal Declaration of Human Rights (UDHR). The ‘social’ domain consists mostly of Twituser data. We use these two domains, as they are not included in training (because the amount of data per language is small), but they have a wide language coverage.

Results The confusion matrices (Figure 4) show that the models have a different sensitivity to do-

main shift. In general, the losses in performance when going to cross-domain settings are large, showing that this is one of the main open challenges for this task. Textcat shows to be remarkably robust, outperforming fastText and LSTM for all test-only domains in all setups (last two columns). NB shows to be the most robust model with respect to domain shift, performing well (>80) for all settings. As opposed to previous settings, GLOT500 is not the most robust model and shows performance drops especially on the test-only domains. The multi-domain model (‘Combined’ in Figure 4) performs better for most model/target domain combinations, an outlier being GLOT500 for social media data. Especially for the more computationally demanding models, performance of some in-domain settings even improved, which is most likely an effect of dataset size. However, this finding indicates that multi-domain training should be considered when building robust language classifiers.

4.5 A language classifier for ~2,000 languages

Setup In the initial size experiments (Section 4.1), we saw that performance between sets of 100 and 1,000 languages only became marginally worse. Therefore, we experiment with scaling up the number of languages further. We still use 1,000 utterances per language for evaluation as well as for training, so exclude all languages with less than 2,000 utterances, resulting in a set of 2,034 lan-

Training	1,000	2,034		2,075	
Testing	1,000	1,000	2,034	1,000	2,075
Textcat	90.78 \pm .11	88.05 \pm .44	87.99 \pm .01	88.72 \pm .47	88.66 \pm .01
NB	95.10 \pm .23	92.44 \pm .46	92.29 \pm .00	93.00 \pm .48	92.81 \pm .01
fastText	95.09 \pm .04	93.43 \pm .12	93.41 \pm .02	93.46 \pm .16	93.42 \pm .01
LSTM	92.36 \pm .26	90.88 \pm .47	90.83 \pm .06	90.92 \pm .47	90.72 \pm .07
GLOT500	96.07 \pm .21	94.37 \pm .30	94.41 \pm .01	94.38 \pm .32	94.39 \pm .02

Table 2: Results (accuracy + standard deviation) on the test splits for a single classifier for 1,000 languages, 2,034 languages, and 2,075 language-script combinations. We evaluate all of them on the 1,000 language sample to gauge the effect of the number of languages.

languages. For all previous experiments, we used a single sub-dataset for each language, meaning that it would be in a single script. For this experiment, we train across domains and datasets, and will thus end up with having multiple scripts per language. To evaluate the effect of this, we also train a model that predicts the language code plus the script (as a single label), similar as in previous work (Brown, 2014; Team et al., 2022; Kargaran et al., 2023a), which leads to a total of 2,075 labels. We also check performance on the 1,000 samples of each seed as a control setting.

Results Results of the evaluation on the 2,034 and 2,075 languages compared to the 1,000 language setting from Section 4.1 are reported in Table 2. There is a consistent drop for all models of approximately 1.5-2.5 percentage points when going from 1,000 languages to 2,034, which is surprisingly large as the drop in performance is similar when going from 100 to 1,000 languages (Section 4.1), which is a factor 10 increase in size (instead of a factor 2). Performance for the 2,034 languages are very close to the 2,075 language-script combinations. This confirms similar contemporary findings by Agarwal et al. (2025), who find that language classification for languages with different scripts performs well as long as all scripts are included during training. The evaluation on the 1,000 languages show that performance of the larger (> 2,000) models is not affected as compared to the 1,000 language model.

5 Analysis

To provide additional insights beyond accuracy, we look into the computational complexity (Section 5.1), and provide a more detailed error analysis of the 2,037 languages model (Section 5.2).

Model	# params
Textcat	40,000
NB	100,000
fastText	4,434,860
LSTM	15,158,772
GLOT500	395,687,155

Table 3: Number of learned weights (# params) per model when training on 100 characters, 1,000 instances, and 100 languages.

5.1 Computational complexity

Setup Instead of evaluating the run-time or carbon emissions of our models, we opt for comparing the total number of weights in a model. We found that there is a too large discrepancy in the efficiency of the implementation of our models,⁶ and prioritize an architectural comparison over an implementation comparison. Therefore, we use the number of weights learned in a model as a proxy to model complexity. We inspect the “average” models, trained on 100 characters, 1,000 instances, and 100 languages for these sizes.

Results The number of parameters (Table 3) show a substantial diversity, where the largest model is 10,000 times larger than the smaller model. If we compare the results of the models on the same setup, we see that Textcat obtains 94.5% of the performance of GLOT500, with only 0.01 % of the weights, which hence might be the preferable option.

⁶Concretely, fastText and GLOT500 seem to be optimized very extensively, while Textcat is extremely slow, although it is computationally the simplest.

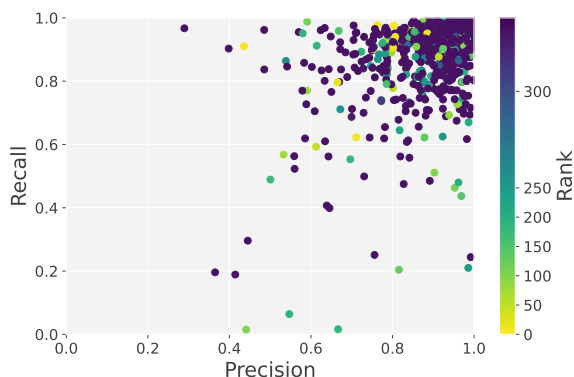


Figure 5: Precision and recall, each circle represents a language. The Wikipedia size is represented by color, where yellow (bright) indicates a high rank (i.e. large size).

5.2 Analysis of largest model

Subwords Even the best-performing model GLOT500 (with 1,000 utterances and 100 characters) still has an error rate of 5.59% on when evaluating our most inclusive setup with 2,034 languages (Section 4.5). Our first hunch was that the model encounters unknown characters, and therefore can not represent the input. However, the training data only had 0.184% of subwords represented as the special UNK token. There were two outliers (Vai and Yintale) with unknown subword rates of 45.7% and 42.8%, followed by 5 languages with a % between 10-20, and only 12 languages with a % between 1-10. Perhaps surprisingly, these languages with more unknown subwords were not among the worst-performing languages. This can be explained by the fact that these are low-resource languages. Even if a part of the text is converted to UNK tokens, the remaining part is distinctive enough for an accurate classification (because their scripts also often are uncommon).

Precision and recall We plot the precision against the recall to find the main weaknesses. Figure 5 shows that precision is generally higher than recall, and even for the most challenging languages, precision is generally above 40%. Arguably, this (precision > recall) is desirable when language identification is used as a filtering step, as we do not want false positives to dilute our data. We also rank the languages based on their Wikipedia size⁷, to check whether better-represented languages are more likely to be overestimated (low precision,

⁷https://en.wikipedia.org/wiki/List_of_Wikipedias

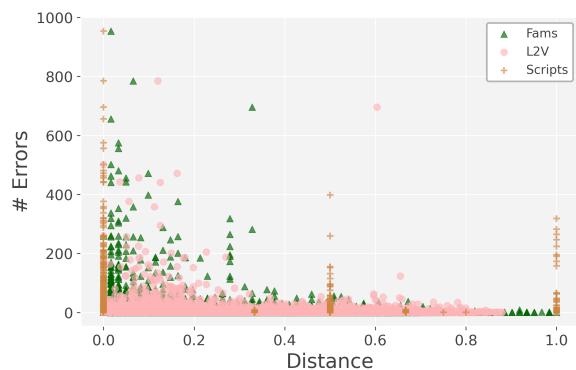


Figure 6: Number of error counts for language pairs plotted against a variety of distance metrics. We normalized all distance metrics to be between 0-1.

high recall), but can find no such trend in the results. We were expecting mainly English to have issues with data purity and overrepresentiveness, which is indeed confirmed by a precision of 82.75 and a recall of 87.80, although it should be well represented in the GLOT500 training data.

Most common confusions From all the errors of the model, 96.7% are cases where both the predicted and the gold language label are used within the same script, and 67.1% are within the same language family. Based on these results, we will perform a more in-depth study into investigating which features correlate with error counts of language pairs. The features we use are: cosine distance over lang2vec representations (Littell et al., 2017)⁸, ratio of script overlap (because the other 2 metrics are also distances we take the inverse), and a distance metric based on the language family in Glottolog. The last metric denotes the number of steps one has to take to go from 1 language to another language in the language family tree.⁹

The scatterplot of the distance values against the error counts (Figure 6) show that larger distances for the metrics generally result in higher performance. The Pearson correlations confirm this with a correlation of -.11 for both lang2vec and language families (p=0.00), but only 0.01 for scripts (p=0.02), which is mostly due to a large number of high overlaps (Latin pairs). Although there seems to be a trend, the correlations are not very high, and accurate predictions of how many errors to expect

⁸Syntax and phonology categories are used, including KNN completions

⁹If languages are in different trees, we use $2 * \max(\text{depth_lang1}, \text{depth_lang2}) + \min(\text{depth_lang1}, \text{depth_lang2})$ to ensure that out-of-family languages get a larger distance.

will be non-trivial based on these variables.

A manual inspection of the most common errors revealed some more interesting trends. We can clearly identify some challenging clusters of languages, where languages are closely related and the inputs might simply not contain enough information. This was the case for example for Dutch and its dialects, a South-Slavic cluster of Bosnian, Croatian, Serbian, and Montenegrin, and the Quechuan language family, especially within the Chinchay branch. Finally, we identified some errors in the data. Yakkha (Devanagari script) is very commonly overpredicted, even for utterances from other scripts (Latin), as it contains programming code in its training data. We also found that the language codes for Dai and Daai are probably confused, as they are a very common confusion for the model, but are not close in the glottolog tree. Finally, we found that TZM (Central Atlas Tamazight) and ZGH (Moroccan Amazigh) are they are commonly used interchangeably (they refer to the same language in Glottolog).

6 Conclusion

In this paper, we have compared simple n-gram frequency profiles with more complex competitors in a systematic variety of setups. We can confirm that the main finding of [Cavnar et al. \(1994\)](#) still holds: “Using N-gram frequency profiles provides a simple and reliable way to categorize documents in a wide range of classification tasks”. Although more complex models outperform the n-gram frequency based model in in-domain setups, if we evaluate cross-domain character n-grams based on frequency heuristic or Naive Bayes have shown remarkable robustness. Cross-domain has also shown to be the most challenging setup, and is probably the most realistic setting, especially when including many languages for which we mainly have religious texts. We show that Multi-domain training partially resolves the performance drop. We also showed that using 1,000 utterances per language with a maximum of 100 characters per utterance already provides very good results. This finding has beneficial implications for future work; training can be done more efficiently, and smoothing over language labels might not be necessary, while more languages can be included. We also found that the number of languages and the amount of different language families or scripts are all not very influential to the performance.

Looking forward, we recommend to use language classifiers with care when they are applied out-of-domain, and where possible include a quantitative and qualitative analysis of its output (regardless of reported in-domain scores). Furthermore, we identify cross-domain language identification as the most prominent direction for future improvements.

Acknowledgements

I would like to express my gratitude to Ralf Brown for discussing and resolving labeling errors in the MIL-TALE data. Furthermore, I’d like to thank the NLPnorth members (and Mike of course). I also gladly thank the anonymous reviewers, who had some very interesting suggestions. Finally, thanks to Victor for showing me that Naive Bayes actually performs well for this task.

Limitations

We focus merely on language identification on the sentence/paragraph level, although there is also a stream of work on language identification on the word level which comes with its own set of challenges ([Burchell et al., 2024](#)), and has less annotated data available. Another constraint of our setup is that we assume one label per text. In some cases texts might be ambiguous with respect to language labels, i.e. they do not contain enough signal to discriminate between labels. Recently, there has been work in this direction with smaller sets of languages ([Chifu et al., 2024](#); [Fedorova et al., 2025](#)).

We use language families as defined in Glottolog, only investigate scripts included in ISO-15924 and use language codes as defined in the ISO-639-3 standard, which is known to have issues and biases ([Morey et al., 2013](#)). We have used lang2vec for measuring typological distance, but it has shown to not be the most reliable solution for this task ([Toossi et al., 2024](#)).

We believe there are still a certain amount of incorrect labels in the data. Common issues are sentences from other languages being included (mainly English), wrong labels on the data-source level, and nonsensical sequences of characters. We believe that we have found most consistent errors in the labels through an automated detection of special script usage, followed by a manual inspection. However, our performance on English for example (85.20 F1) suggests that there are still some errors. Manual inspection revealed that overprediction on

English occurred mainly on short sentences, sentences with names (of named entities), and quotes. Whereas utterances with other gold labels classified as English, are mainly from datasets where these phenomena occur in the training data.

References

- Noëmi Aeppli, Çağrı Çöltekin, Rob Van Der Goot, Tommi Jauhiainen, Mourhaf Kazzaz, Nikola Ljubešić, Kai North, Barbara Plank, Yves Scherrer, and Marcos Zampieri. 2023. [Findings of the VarDial evaluation campaign 2023](#). In *Tenth Workshop on NLP for Similar Languages, Varieties and Dialects (VarDial 2023)*, pages 251–261, Dubrovnik, Croatia. Association for Computational Linguistics.
- Milind Agarwal, Joshua Otten, and Antonios Anastasopoulos. 2025. [Script-agnosticism and its impact on language identification for Dravidian languages](#). In *Proceedings of the 2025 Conference of the Nations of the Americas Chapter of the Association for Computational Linguistics: Human Language Technologies (Volume 1: Long Papers)*, pages 7364–7384, Albuquerque, New Mexico. Association for Computational Linguistics.
- Rupal Bhargava, Yashvardhan Sharma, Shubham Sharma, and Abhinav Baid. 2015. Query labelling for indic languages using a hybrid approach. In *FIRE Workshops*, pages 40–42.
- Ralf Brown. 2014. [Non-linear mapping for improved identification of 1300+ languages](#). In *Proceedings of the 2014 Conference on Empirical Methods in Natural Language Processing (EMNLP)*, pages 627–632, Doha, Qatar. Association for Computational Linguistics.
- Laurie Burchell, Alexandra Birch, Nikolay Bogoychev, and Kenneth Heafield. 2023. [An open dataset and model for language identification](#). In *Proceedings of the 61st Annual Meeting of the Association for Computational Linguistics (Volume 2: Short Papers)*, pages 865–879, Toronto, Canada. Association for Computational Linguistics.
- Laurie Burchell, Alexandra Birch, Robert P Thompson, and Kenneth Heafield. 2024. Code-switched language identification is harder than you think. *arXiv preprint arXiv:2402.01505*.
- Giacomo Camposampiero, Quynh Anh Nguyen, and Francesco Di Stefano. 2022. [The curious case of logistic regression for Italian languages and dialects identification](#). In *Proceedings of the Ninth Workshop on NLP for Similar Languages, Varieties and Dialects*, pages 86–98, Gyeongju, Republic of Korea. Association for Computational Linguistics.
- William B Cavnar, John M Trenkle, et al. 1994. N-gram-based text categorization. In *Proceedings of SDAIR-94, 3rd annual symposium on document analysis and information retrieval*, page 14, Las Vegas, NV.
- Jordan Cazamias, Chinmayi Dixit, and Martina Marek. 2015. Large-scale language classification-writing a detector for 200 languages on twitter.
- Wei-Rui Chen, Ife Adebara, Khai Duy Doan, Qisheng Liao, and Muhammad Abdul-Mageed. 2023. Fumbling in babel: An investigation into chatgpt’s language identification ability. *arXiv preprint arXiv:2311.09696*.
- Adrian-Gabriel Chifu, Goran Glavaš, Radu Tudor Ionescu, Nikola Ljubešić, Aleksandra Miletić, Filip Miletić, Yves Scherrer, and Ivan Vulić. 2024. [VarDial evaluation campaign 2024: Commonsense reasoning in dialects and multi-label similar language identification](#). In *Proceedings of the Eleventh Workshop on NLP for Similar Languages, Varieties, and Dialects (VarDial 2024)*, pages 1–15, Mexico City, Mexico. Association for Computational Linguistics.
- Alexis Conneau and Guillaume Lample. 2019. Cross-lingual language model pretraining. *Advances in neural information processing systems*, 32.
- A. Seza Doğruöz, Sunayana Sitaram, Barbara E. Bullock, and Almeida Jacqueline Toribio. 2021. [A survey of code-switching: Linguistic and social perspectives for language technologies](#). 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 1654–1666, Online. Association for Computational Linguistics.
- Mariia Fedorova, Jonas Sebulon Frydenberg, Victoria Handford, Victoria Ovedie Chruickshank Langø, Solveig Helene Willoch, Marthe Løken Midtgaard, Yves Scherrer, Petter Mæhlum, and David Samuel. 2025. [Multi-label Scandinavian language identification \(SLIDE\)](#). In *Proceedings of the Third Workshop on Resources and Representations for Under-Resourced Languages and Domains (RESOURCEFUL-2025)*, pages 179–189, Tallinn, Estonia. University of Tartu Library, Estonia.
- Alex Graves and Jürgen Schmidhuber. 2005. Framewise phoneme classification with bidirectional lstm and other neural network architectures. *Neural networks*, 18(5-6):602–610.
- Harald Hammarström, Robert Forkel, Martin Haspelmath, and Sebastian Bank. 2023. [Glottolog 4.8](#). Leipzig: Max Planck Institute for Evolutionary Anthropology.
- Sepp Hochreiter and Jürgen Schmidhuber. 1997. Long short-term memory. *Neural computation*, 9(8):1735–1780.
- Ayyoob ImaniGooghari, Peiqin Lin, Amir Hossein Kargaran, Silvia Severini, Masoud Jalili Sabet, Nora Kassner, Chunlan Ma, Helmut Schmid, André Martins, François Yvon, and Hinrich Schütze. 2023. [Glott500: Scaling multilingual corpora and language models to 500 languages](#). In *Proceedings of the 61st Annual Meeting of the Association for Computational*

- Linguistics (Volume 1: Long Papers)*, pages 1082–1117, Toronto, Canada. Association for Computational Linguistics.
- Tommi Jauhiainen, Marco Lui, Marcos Zampieri, Timothy Baldwin, and Krister Lindén. 2019. Automatic language identification in texts: A survey. *Journal of Artificial Intelligence Research*, 65:675–782.
- Armand Joulin, Edouard Grave, Piotr Bojanowski, and Tomas Mikolov. 2017. **Bag of tricks for efficient text classification**. In *Proceedings of the 15th Conference of the European Chapter of the Association for Computational Linguistics: Volume 2, Short Papers*, pages 427–431, Valencia, Spain. Association for Computational Linguistics.
- Amir Kargaran, Ayyoob Imani, François Yvon, and Hinrich Schuetze. 2023a. **GlottLID: Language identification for low-resource languages**. In *Findings of the Association for Computational Linguistics: EMNLP 2023*, pages 6155–6218, Singapore. Association for Computational Linguistics.
- Amir Hossein Kargaran, François Yvon, and Hinrich Schütze. 2023b. Glotscript: A resource and tool for low resource writing system identification. *arXiv preprint arXiv:2309.13320*.
- Julia Kreutzer, Isaac Caswell, Lisa Wang, Ahsan Wahab, Daan van Esch, Nasanbayar Ulzii-Orshikh, Allahsera Tapo, Nishant Subramani, Artem Sokolov, Claytone Sikasote, Monang Setyawan, Supheakmungkol Sarin, Sokhar Samb, Benoît Sagot, Clara Rivera, Annette Rios, Isabel Papadimitriou, Salomey Osei, Pedro Ortiz Suarez, Iroko Orife, Kelechi Ogueji, Andre Niyongabo Rubungo, Toan Q. Nguyen, Mathias Müller, André Müller, Shamsuddeen Hassan Muhammad, Nanda Muhammad, Ayanda Mnyakeni, Jamshidbek Mirzakhlov, Tapiwanashe Matangira, Colin Leong, Nze Lawson, Sneha Kudugunta, Yacine Jernite, Mathias Jenny, Orhan Firat, Bonaventure F. P. Dossou, Sakhile Dlamini, Nisansa de Silva, Sakine Çabuk Ballı, Stella Biderman, Alessia Battisti, Ahmed Baruwa, Ankur Bapna, Pallavi Baljekar, Israel Abebe Azime, Ayodele Awokoya, Duygu Ataman, Orevaoghene Ahia, Oghenefego Ahia, Sweta Agrawal, and Mofetoluwa Adeyemi. 2022. **Quality at a glance: An audit of web-crawled multilingual datasets**. *Transactions of the Association for Computational Linguistics*, 10:50–72.
- Patrick Littell, David R. Mortensen, Ke Lin, Katherine Kairis, Carlisle Turner, and Lori Levin. 2017. **URIEL and lang2vec: Representing languages as typological, geographical, and phylogenetic vectors**. In *Proceedings of the 15th Conference of the European Chapter of the Association for Computational Linguistics: Volume 2, Short Papers*, pages 8–14, Valencia, Spain. Association for Computational Linguistics.
- Marco Lui and Timothy Baldwin. 2011. **Cross-domain feature selection for language identification**. In *Proceedings of 5th International Joint Conference on Natural Language Processing*, pages 553–561, Chiang Mai, Thailand. Asian Federation of Natural Language Processing.
- Marco Lui and Timothy Baldwin. 2014a. **Accurate language identification of Twitter messages**. In *Proceedings of the 5th Workshop on Language Analysis for Social Media (LASM)*, pages 17–25, Gothenburg, Sweden. Association for Computational Linguistics.
- Marco Lui and Timothy Baldwin. 2014b. **Accurate language identification of twitter messages**. In *Proceedings of the 5th Workshop on Language Analysis for Social Media (LASM)*, pages 17–25, Gothenburg, Sweden. Association for Computational Linguistics.
- Martin Majliš. 2012. **Yet another language identifier**. In *Proceedings of the Student Research Workshop at the 13th Conference of the European Chapter of the Association for Computational Linguistics*, pages 46–54, Avignon, France. Association for Computational Linguistics.
- Stephen Morey, Mark W Post, and Victor A Friedman. 2013. The language codes of iso 639: A premature, ultimately unobtainable, and possibly damaging standardization. *PARADISEC RRR Conference*.
- F. Pedregosa, G. Varoquaux, A. Gramfort, V. Michel, B. Thirion, O. Grisel, M. Blondel, P. Prettenhofer, R. Weiss, V. Dubourg, J. Vanderplas, A. Passos, D. Cournapeau, M. Brucher, M. Perrot, and E. Duchesnay. 2011. Scikit-learn: Machine learning in Python. *Journal of Machine Learning Research*, 12:2825–2830.
- Nathaniel Robinson, Perez Ogayo, David R. Mortensen, and Graham Neubig. 2023. **ChatGPT MT: Competitive for high- (but not low-) resource languages**. In *Proceedings of the Eighth Conference on Machine Translation*, pages 392–418, Singapore. Association for Computational Linguistics.
- NLLB Team, Marta R. Costa-jussà, James Cross, Onur Çelebi, Maha Elbayad, Kenneth Heafield, Kevin Hefernan, Elahe Kalbassi, Janice Lam, Daniel Licht, Jean Maillard, Anna Sun, Skyler Wang, Guillaume Wenzek, Al Youngblood, Bapi Akula, Loic Barrault, Gabriel Mejia Gonzalez, Prangthip Hansanti, John Hoffman, Semarley Jarrett, Kaushik Ram Sadagopan, Dirk Rowe, Shannon Spruit, Chau Tran, Pierre Andrews, Necip Fazil Ayan, Shruti Bhosale, Sergey Edunov, Angela Fan, Cynthia Gao, Vedanuj Goswami, Francisco Guzmán, Philipp Koehn, Alexandre Mourachko, Christophe Ropers, Safiyyah Saleem, Holger Schwenk, and Jeff Wang. 2022. No language left behind: Scaling human-centered machine translation. *arXiv preprint arXiv:2207.04672*.
- Mads Toftrup, Søren Asger Sørensen, Manuel R. Ciosici, and Ira Assent. 2021. **A reproduction of apple’s bi-directional LSTM models for language identification in short strings**. In *Proceedings of the*

- 16th Conference of the European Chapter of the Association for Computational Linguistics: Student Research Workshop, pages 36–42, Online. Association for Computational Linguistics.
- Hasti Toossi, Guo Huai, Jinyu Liu, Eric Khiu, A. Seza Doğruöz, and En-Shiun Lee. 2024. [A reproducibility study on quantifying language similarity: The impact of missing values in the URIEL knowledge base](#). In *Proceedings of the 2024 Conference of the North American Chapter of the Association for Computational Linguistics: Human Language Technologies (Volume 4: Student Research Workshop)*, pages 233–241, Mexico City, Mexico. Association for Computational Linguistics.
- Gertjan van Noord. 1997. *Textcat*.
- Daniel Varab and Natalie Schluter. 2021. [MasiveSumm: a very large-scale, very multilingual, news summarisation dataset](#). In *Proceedings of the 2021 Conference on Empirical Methods in Natural Language Processing*, pages 10150–10161, Online and Punta Cana, Dominican Republic. Association for Computational Linguistics.
- Genta Winata, Alham Fikri Aji, Zheng Xin Yong, and Thamar Solorio. 2023. [The decades progress on code-switching research in NLP: A systematic survey on trends and challenges](#). In *Findings of the Association for Computational Linguistics: ACL 2023*, pages 2936–2978, Toronto, Canada. Association for Computational Linguistics.
- Marcos Zampieri, Liling Tan, Nikola Ljubešić, and Jörg Tiedemann. 2014. [A report on the DSL shared task 2014](#). In *Proceedings of the First Workshop on Applying NLP Tools to Similar Languages, Varieties and Dialects*, pages 58–67, Dublin, Ireland. Association for Computational Linguistics and Dublin City University.
- Marcos Zampieri, Liling Tan, Nikola Ljubešić, Jörg Tiedemann, and Preslav Nakov. 2015. [Overview of the DSL shared task 2015](#). In *Proceedings of the Joint Workshop on Language Technology for Closely Related Languages, Varieties and Dialects*, pages 1–9, Hissar, Bulgaria. Association for Computational Linguistics.
- Daniel Zeman, Joakim Nivre, Mitchell Abrams, Elia Ackermann, Noëmi Aepli, Hamid Aghaei, Željko Agić, Amir Ahmadi, Lars Ahrenberg, Chika Kennedy Ajede, Salih Furkan Akkurt, Gabrielè Aleksandraviciūtė, Ika Alfina, Avner Algom, Khalid Alnajjar, Chiara Alzetta, Erik Andersen, Lene Antonsen, Tatsuya Aoyama, Katya Aplonova, Angelina Aquino, Carolina Aragon, Glyd Aranes, Maria Jesus Aranzabe, Bilge Nas Arican, Hórunn Arnardóttir, Gashaw Arutie, Jessica Naraiswari Arwidarasti, Masayuki Asahara, Katla Ásgeirsdóttir, Deniz Baran Aslan, Cengiz Asmazoğlu, Luma Ateyah, Furkan Atmaca, Mohammed Attia, Aitziber Atutxa, Liesbeth Augustinus, Mariana Avelãs, Elena Badmaeva, Keerthana Balasubramani, Miguel Ballesteros, Esha Banerjee, Sebastian Bank, Verginica Barbu Mititelu, Starkaður Barkarson, Rodolfo Basile, Victoria Basmov, Colin Batchelor, John Bauer, Seyyit Talha Bedir, Shabnam Behzad, Kepa Bengoetxea, İbrahim Benli, Yifat Ben Moshe, Gözde Berk, Riyaz Ahmad Bhat, Erica Biagetti, Eckhard Bick, Agnė Bielinskienė, Kristín Bjarnadóttir, Rogier Blokland, Victoria Bobicev, Loïc Boizou, Emanuel Borges Völker, Carl Börstell, Cristina Bosco, Gosse Bouma, Sam Bowman, Adriane Boyd, Anouck Braggaar, António Branco, Kristina Brokaitė, Aljoscha Burchardt, Marisa Campos, Marie Candito, Bernard Caron, Gauthier Caron, Catarina Carvalheiro, Rita Carvalho, Lauren Cassidy, Maria Clara Castro, Sérgio Castro, Tatiana Cavalcanti, Gülşen Cebiroğlu Eryiğit, Flavio Massimiliano Cecchini, Giuseppe G. A. Celano, Slavomír Čeplo, Neslihan Cesur, Savas Cetin, Özlem Çetinoğlu, Fabricio Chalub, Liyanage Chamila, Shweta Chauhan, Ethan Chi, Taishi Chika, Yongseok Cho, Jinho Choi, Jayeol Chun, Juyeon Chung, Alessandra T. Cignarella, Silvie Cinková, Aurélie Collomb, Çağrı Çöltekin, Miriam Connor, Daniela Corbetta, Francisco Costa, Marine Courtin, Mihaela Cristescu, Ingerid Løyning Dale, Philemon Daniel, Elizabeth Davidson, Leonel Figueiredo de Alencar, Mathieu Dehouck, Martina de Laurentiis, Marie-Catherine de Marneffe, Valeria de Paiva, Mehmet Oguz Derin, Elvis de Souza, Arantza Diaz de Ilarraza, Carly Dickerson, Arawinda Dinakaramani, Elisa Di Nuovo, Bamba Dione, Peter Dirix, Kaja Dobrovoljc, Adrian Doyle, Timothy Dozat, Kira Droganova, Puneet Dwivedi, Christian Ebert, Hanne Eckhoff, Masaki Eguchi, Sandra Eiche, Marhaba Eli, Ali Elkahky, Binyam Ephrem, Olga Erina, Tomaž Erjavec, Farah Essaidi, Aline Etienne, Wograine Evelyn, Sidney Facundes, Richárd Farkas, Federica Favero, Jannatul Ferdaousi, Marília Fernanda, Hector Fernandez Alcalde, Amal Fethi, Jennifer Foster, Cláudia Freitas, Kazunori Fujita, Katarína Gajdošová, Daniel Galbraith, Federica Gamba, Marcos Garcia, Moa Gärdenfors, Fabrício Ferraz Gerardi, Kim Gerdes, Luke Gessler, Filip Ginter, Gustavo Godoy, Iakes Goenaga, Koldo Gojenola, Memduh Gökırmak, Yoav Goldberg, Xavier Gómez Guinovart, Berta González Saavedra, Bernadeta Griciūtė, Matias Grioni, Loïc Grobol, Normunds Grūzītis, Bruno Guillaume, Céline Guillot-Barbance, Tunga Güngör, Nizar Habash, Hinrik Hafsteinsson, Jan Hajič, Jan Hajič jr., Mika Hämäläinen, Linh Hà Mỹ, Na-Rae Han, Muhammad Yudistira Hanifmuti, Takahiro Harada, Sam Hardwick, Kim Harris, Dag Haug, Johannes Heinecke, Oliver Hellwig, Felix Hennig, Barbora Hladká, Jaroslava Hlaváčová, Florinel Hociung, Petter Hohle, Marivel Huerta Mendez, Jena Hwang, Takumi Ikeda, Anton Karl Ingason, Radu Ion, Elena Irimia, Olájídé Ishola, Artan Islamaj, Kaoru Ito, Siratun Jannat, Tomáš Jelínek, Apoorva Jha, Katharine Jiang, Anders Johannsen, Hildur Jónsdóttir, Fredrik Jørgensen, Markus Juutinen, Hüner Kaşıkara, Nadezhda Kabaeva, Sylvain Kahane, Hiroshi Kanayama, Jenna Kanerva, Neslihan Kara, Ritván Karahóga, Andre Kåsen, Tolga Kayadelen, Sarveswaran Kengatharaiyer, Václava Kettnerová, Jesse Kirchner, Elena

Klementieva, Elena Klyachko, Arne Köhn, Abdulatif Köksal, Kamil Kopacewicz, Timo Korkiakangas, Mehmet Köse, Alexey Koshevoy, Natalia Kotsyba, Jolanta Kovalevskaitė, Simon Krek, Parameswari Krishnamurthy, Sandra Kübler, Adrian Kuqi, Oğuzhan Kuyrukçu, Aslı Kuzgun, Sookyoung Kwak, Kris Kyle, Veronika Laippala, Lorenzo Lambertino, Tatiana Lando, Septina Dian Larasati, Alexei Lavrentiev, John Lee, Phuong Lê Hồng, Alessandro Lenci, Saran Lertpradit, Herman Leung, Maria Levina, Lauren Levine, Cheuk Ying Li, Josie Li, Keying Li, Yixuan Li, Yuan Li, KyungTae Lim, Bruna Lima Padovani, Yi-Ju Jessica Lin, Krister Lindén, Yang Janet Liu, Nikola Ljubešić, Olga Loginova, Stefano Lusito, Andry Luthfi, Mikko Luukko, Olga Lyashevskaya, Teresa Lynn, Vivien Macketanz, Menel Mahamdi, Jean Maillard, Ilya Makarchuk, Aibek Makazhanov, Michael Mandl, Christopher Manning, Ruli Manurung, Büşra Marşan, Cătălina Mărănduc, David Mareček, Katrin Marheinecke, Stella Markantonatou, Héctor Martínez Alonso, Lorena Martín Rodríguez, André Martins, Cláudia Martins, Jan Mašek, Hiroshi Matsuda, Yuji Matsumoto, Alessandro Mazzei, Ryan McDonald, Sarah McGuinness, Gustavo Mendonça, Tatiana Merzhevich, Niko Miekka, Aaron Miller, Karina Mischenkova, Anna Missilä, Cătălin Mititelu, Maria Mitrofan, Yusuke Miyao, AmirHossein Mojiri Foroushani, Judit Molnár, Amirsaeid Moloodi, Simonetta Montemagni, Amir More, Laura Moreno Romero, Giovanni Moretti, Shinsuke Mori, Tomohiko Morioka, Shigeki Moro, Bjartur Mortensen, Bohdan Moskalevskyi, Kadri Muischnek, Robert Munro, Yugo Murawaki, Kaili Müürisep, Pinkey Nainwani, Mariam Nakhlé, Juan Ignacio Navarro Horñiacek, Anna Nedoluzhko, Gunta Nešpore-Bērzkalne, Manuela Nevaci, Luong Nguyễn Thị, Huyền Nguyễn Thị Minh, Yoshihiro Nikaido, Vitaly Nikolaev, Rattima Nitisaroj, Alireza Nourian, Hanna Nurmi, Stina Ojala, Atul Kr. Ojha, Hulda Óladóttir, Adédayo Olúòkun, Mai Omura, Emeka Onwuegbuzia, Noam Ordan, Petya Osenova, Robert Östling, Lilja Øvrelid, Şaziye Betül Özateş, Merve Özçelik, Arzucan Özgür, Balkız Öztürk Başaran, Teresa Paccosi, Alessio Palmero Aprosio, Anastasia Panova, Hyunji Hayley Park, Niko Partanen, Elena Pascual, Marco Passarotti, Agnieszka Patejuk, Guilherme Paulino-Passos, Giulia Pedonese, Angelika Peljak-Łapińska, Siyao Peng, Siyao Logan Peng, Rita Pereira, Sílvia Pereira, Cenel-Augusto Perez, Natalia Perkova, Guy Perrier, Slav Petrov, Daria Petrova, Andrea Peverelli, Jason Phelan, Jussi Piitulainen, Yuval Pinter, Clara Pinto, Tommi A Pirinen, Emily Pitler, Magdalena Plamada, Barbara Plank, Thierry Poibeau, Larisa Ponomareva, Martin Popel, Lauma Pretkalniņa, Sophie Prévost, Prokopis Prokopidis, Adam Przepiórkowski, Robert Pugh, Tiina Puolakainen, Sampo Pyysalo, Peng Qi, Andrea Querido, Andriela Rääbis, Alexandre Rademaker, Mizanur Rahoman, Taraka Rama, Loganathan Ramasamy, Joana Ramos, Fam Rashel, Mohammad Sadegh Rasooli, Vinit Ravishankar, Livy Real, Petru Rebeja, Siva Reddy, Mathilde Regnault, Georg Rehm, Arij Riabi, Ivan Riabov, Michael Riebler,

Erika Rimkutė, Larissa Rinaldi, Laura Rituma, Putri Rizqiyah, Luisa Rocha, Eiríkur Rögnvaldsson, Ivan Roksandic, Mykhailo Romanenko, Rudolf Rosa, Valentin Roşca, Davide Rovati, Ben Roznoyer, Olga Rudina, Jack Rueter, Kristján Rúnarsson, Shoval Sadde, Pegah Safari, Aleksí Sahala, Shadi Saleh, Alessio Salomoni, Tanja Samardžić, Stephanie Samson, Manuela Sanguinetti, Ezgi Sanıyar, Dage Särg, Marta Sartor, Mitsuya Sasaki, Baiba Saulīte, Yanin Sawanakunanon, Shefali Saxena, Kevin Scannell, Salvatore Scarlata, Nathan Schneider, Sebastian Schuster, Lane Schwartz, Djamé Seddah, Wolfgang Seeker, Mojgan Seraji, Syeda Shahzadi, Mo Shen, Atsuko Shimada, Hiroyuki Shirasu, Yana Shishkina, Muh Shohibussirri, Maria Shvedova, Janine Siewert, Einar Freyr Sigurðsson, João Silva, Aline Silveira, Natalia Silveira, Sara Silveira, Maria Simi, Radu Simionescu, Katalin Simkó, Mária Šimková, Haukur Barri Símonarson, Kiril Simov, Dmitri Sitchinava, Ted Sither, Maria Skachedubova, Aaron Smith, Isabela Soares-Bastos, Per Erik Solberg, Barbara Sonnenhauser, Shafi Sourov, Rachele Sprugnoli, Vivan Stamou, Steinhórfur Steingrímsson, Antonio Stella, Abishek Stephen, Milan Straka, Emmett Strickland, Jana Strnadová, Alane Suhr, Yogi Lesmana Sulestio, Umut Sulubacak, Shingo Suzuki, Daniel Swanson, Zsolt Szántó, Chihiro Taguchi, Dima Taji, Fabio Tamburini, Mary Ann C. Tan, Takaaki Tanaka, Dipta Tanaya, Mirko Tavoni, Samson Tella, Isabelle Tellier, Marinella Testori, Guillaume Thomas, Sara Tonelli, Liisi Torga, Marsida Toska, Trond Trosterud, Anna Trukhina, Reut Tsarfaty, Utku Türk, Francis Tyers, Sveinbjörn Hórfarson, Vilhjálmur Hörsteinsson, Sumire Uematsu, Roman Untilov, Zdeňka Uřešová, Larraitz Uria, Hans Uszkoreit, Andrius Utka, Elena Vagnoni, Sowmya Vajjala, Socrates Vak, Rob van der Goot, Martine Vanhove, Daniel van Niekerk, Gertjan van Noord, Viktor Varga, Uliana Vedenina, Giulia Venturi, Veronika Vincze, Natalia Vlasova, Aya Wakasa, Joel C. Wallenberg, Lars Wallin, Abigail Walsh, Jonathan North Washington, Maximilian Wendt, Paul Widmer, Shira Wigderson, Sri Hartati Wijono, Seyi Williams, Mats Wirén, Christian Wittern, Tsegay Woldemariam, Tak-sum Wong, Alina Wróblewska, Mary Yako, Kayo Yamashita, Naoki Yamazaki, Chunxiao Yan, Koichi Yasuoka, Marat M. Yavrumyan, Arife Betül Yenice, Olcay Taner Yıldız, Zhuoran Yu, Arlisa Yuliawati, Zdeněk Žabokrtský, Shorouq Zahra, Amir Zeldes, He Zhou, Hanzhi Zhu, Yilun Zhu, Anna Zhuravleva, and Rayan Ziane. 2023. [Universal dependencies 2.12](#). LINDAT/CLARIAH-CZ digital library at the Institute of Formal and Applied Linguistics (ÚFAL), Faculty of Mathematics and Physics, Charles University.

parameter	range
LR	0.0001 , 0.00001
Batch size	16 , 32, 64
Dropout	0.0 , 0.2, 0.3
Hidden size	120, 768
Num layers	1, 2

Table 4: Hyperparameter ranges evaluated for the LSTM model, best ones are in bold, and are the ones used in the paper.

A LSTM tuning

We tuned the most important hyperparameters for our LSTM model on a set of 100 random languages. The ranges we evaluated are reported in Table 4.

B Standard deviation for size experiments

In Figure 7 we report the standard deviation for all experiments of Section 4.1.

C Language models comparison

We compared the performance of a variety of multilingual language models on an earlier release of the MIL-TALE dataset (including 1,277 languages), without any constraints like character size limitations. Figure 8 shows that GLOT500 performs slightly favorable compared to its competitors. The Byt5 model crashed during training, but performance was substantially lower and these experiments are computationally costly, so we never finished the full training procedure.

D Cleaning procedure

1. We group all utterances of each language label of each dataset; we clean only on the label level (i.e. we only remove a language completely), and not on the instance level to keep the data more realistic.
2. We remove all data from dialects, macro-languages, and datasets with language codes not found in the ISO-639-3 standard. Expired language codes are mapped, following the official 639-3 updates.
3. We standardize the domain labels by creating a mapping.
4. We find the most common script based on the ISO 15924 standard (same as Unicode), and check whether this script is supposed

to be used for this language with the data from Kargaran et al. (2023b). Note that this also catches some erroneous encoding issues etc. (as the script would then be ‘Common’ for example).

5. We manually inspect the texts of odd combinations and frequencies of scripts, and found some XML labels and other markup. We either corrected these in the original data source, or in our pre-processing scripts.

E Per language performance

We report the F1 scores and precision-recall for each language in Table 5 until Table 10. These results are from the 2,034 settings, where we include all languages as a label (so 1 label can have multiple scripts).

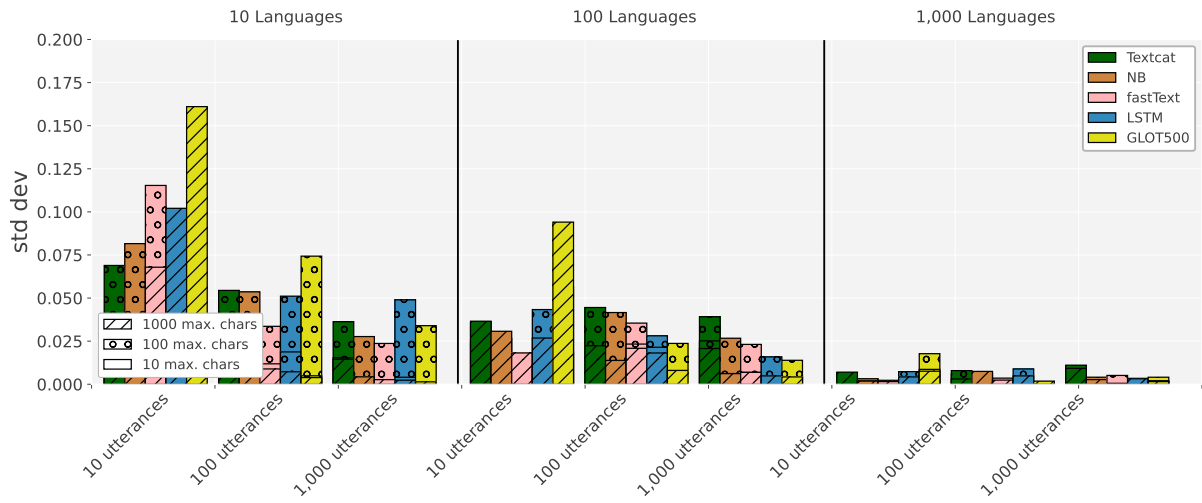


Figure 7: Standard deviations for all experiments with different sizes (equivalent structure as Figure 2).

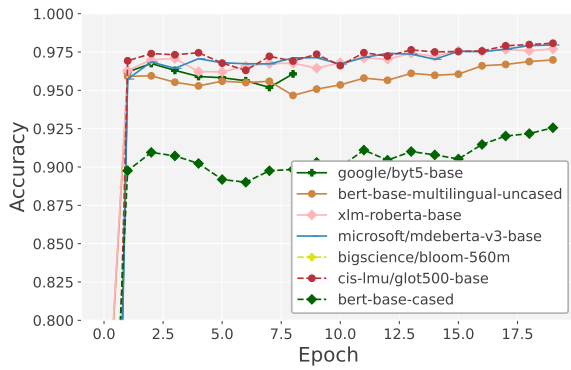


Figure 8: Comparison of different language models over time (i.e. number of epochs).

Lang	Textcat				NB				fastText				LSTM				GLOTF500				Lang	Textcat				NB				fastText				LSTM				GLOTF500				Lang	Textcat				NB				fastText				LSTM				GLOTF500																																																																																		
	F1	Pre	Rec	Rec	F1	Pre	Rec	Rec	F1	Pre	Rec	Rec	F1	Pre	Rec	Rec	F1	Pre	Rec	Rec		F1	Pre	Rec	Rec	F1	Pre	Rec	Rec	F1	Pre	Rec	Rec	F1	Pre	Rec	Rec	F1	Pre	Rec	Rec		F1	Pre	Rec	Rec																																																																																															
sas	80.6	27.3	82.1	28.4	74.7	3.9	73.2	4.8	69.8	9.9	73.5	1.1	90.8	0.9	96.1	1.9	95.8	2.4	96.9	0.5	tzm	1.3	90.2	64.9	48.6	79.5	14.0	73.0	-1.1	77.5	7.7	tzr	96.6	0.9	98.4	-0.5	98.0	-0.0	99.3	1.2	98.7	1.0	ubl	93.2	-0.6	97.6	-3.7	97.8	-0.2	96.4	-1.3	99.0	-1.1	ubr	97.0	-3.2	99.4	-1.0	98.4	-2.2	98.3	-1.4	99.2	-0.9	udg	82.2	0.2	88.6	7.7	97.4	-0.3	94.8	-2.8	96.8	1.8	udm	79.9	15.1	81.6	-10.0	92.3	10.3	88.2	15.8	97.2	4.0	uhn	99.7	-0.4	99.6	-0.8	99.7	-0.3	99.8	0.0	99.9	-0.1	uig	64.8	51.0	77.1	36.6	94.9	0.2	92.5	-1.2	97.1	0.3	ujr	76.6	-7.0	79.9	20.1	84.3	-9.7	70.8	-31.7	90.6	-9.6	ukw	99.3	-0.8	99.3	-1.5	99.4	-0.5	99.0	-0.9	99.7	-0.1	ulv	97.0	-4.6	97.0	-5.3	98.2	-1.5	98.2	-0.2	99.4	-0.1

Table 9: Results per language of the model with all 2,034 languages in our benchmarks. We report F1 score, and precision-recall.

Lang	Textcat		NB		fasText		LSTM		GLOT500	
	F1	Prec-Rec	F1	Prec-Rec	F1	Prec-Rec	F1	Prec-Rec	F1	Prec-Rec
yam	98.5	0.2	99.9	-0.1	98.6	-0.2	98.4	1.1	99.1	-0.3
yam	92.7	-0.1	97.2	3.4	94.6	-0.1	93.8	-3.5	97.0	1.3
yao	87.5	10.9	92.1	6.3	90.1	5.3	85.8	2.3	90.9	4.9
yap	89.7	5.0	94.3	8.4	92.9	11.6	92.9	11.0	94.3	9.7
yaq	97.8	-2.5	99.6	-0.5	98.8	0.7	98.5	0.9	99.1	-0.6
yas	92.0	3.4	95.8	0.8	95.3	0.9	94.7	0.4	93.5	-2.6
yat	96.2	-1.6	92.5	-13.4	96.4	3.0	96.6	2.0	98.0	0.7
yaz	99.1	-1.7	99.5	-1.0	99.8	-0.3	99.9	0.1	99.9	-0.2
yba	96.6	5.1	96.4	3.5	96.8	6.0	97.0	5.5	97.7	4.3
ybb	96.3	6.5	97.0	4.5	96.4	-2.3	97.4	-1.7	96.7	-3.4
ybb	46.2	46.5	33.4	-44.4	44.7	-67.7	44.0	-63.7	44.6	-68.4
ybv	86.3	-3.0	91.8	7.9	95.0	-5.8	97.0	-2.4	98.5	-0.2
ycl	99.2	-1.5	99.5	-1.1	99.6	-0.6	99.9	-0.2	99.8	-0.4
ycn	97.8	-3.3	99.6	-0.5	99.1	-0.6	99.2	0.1	99.4	-0.3
ydd	99.2	0.5	98.1	-1.8	99.9	0.0	99.6	0.6	99.9	-0.1
yda	95.5	-2.6	98.7	-1.5	99.4	0.6	98.8	-0.6	99.4	-0.3
yim	93.1	7.1	94.9	5.9	92.4	3.9	89.5	0.8	94.2	7.0
yka	98.7	0.2	98.7	-1.7	98.5	-0.6	98.8	1.5	98.9	2.1
yle	99.2	1.4	99.7	-0.4	98.5	1.6	99.1	1.0	98.8	1.0
yli	88.6	1.1	94.0	2.6	93.7	4.4	88.2	0.1	91.7	-1.9
ym	98.4	0.0	98.7	0.1	97.6	-1.5	96.6	0.5	98.3	-0.5
yml	77.0	16.3	89.6	8.5	90.9	3.2	86.6	-0.1	94.8	0.2
yom	97.5	-4.7	98.8	-2.1	99.5	-0.5	99.5	-0.5	99.5	-0.7
yor	90.4	11.2	96.9	3.7	94.3	-1.5	95.1	2.3	97.1	0.4
yrb	95.7	-2.3	98.5	-0.7	98.0	-0.6	96.1	-0.5	98.8	0.4
yre	95.8	-4.0	99.1	-1.5	97.6	1.4	97.2	2.8	98.9	1.2
yri	96.8	2.9	98.8	0.8	96.9	-1.0	95.7	1.3	97.0	-1.6
yua	94.0	6.4	94.6	1.7	91.2	-3.9	90.5	-4.8	94.3	-1.8
yue	70.7	27.2	54.7	59.7	72.1	4.7	94.1	5.0	97.3	-0.2
yuj	95.8	-1.1	99.0	-1.5	98.4	-2.2	98.0	1.9	98.6	-2.0
yut	99.2	-0.3	99.4	-0.8	99.6	-0.2	99.1	-0.1	99.4	-0.9
yuw	98.6	-1.7	98.2	-3.4	98.7	-1.6	98.9	-1.0	99.5	-0.1
yuz	99.1	-1.2	96.5	-7.1	99.6	-0.4	99.7	0.1	99.7	-0.3
yva	96.0	1.0	98.2	1.4	97.0	2.0	95.7	1.3	97.2	1.9
zaa	98.9	-0.6	99.2	-1.1	98.9	-0.8	98.8	-1.1	99.5	-0.6
zab	98.8	0.2	98.7	0.5	97.6	-2.2	97.6	-1.9	98.6	-1.2
zac	98.3	0.9	99.0	-0.2	98.8	-0.2	98.5	-0.9	99.6	0.3
zad	95.9	-5.0	96.9	-5.0	96.2	-3.7	95.6	-1.5	98.3	-0.6
zae	96.8	-0.2	98.7	-0.4	97.4	0.0	96.0	0.0	97.8	1.5
zaf	94.4	-3.2	98.3	0.1	97.2	0.6	96.1	-1.4	98.1	0.4
zaj	40.8	-6.2	79.5	-7.2	75.3	-6.4	58.8	-1.7	75.6	-9.8
zam	95.2	-5.7	98.9	-2.0	98.2	-0.4	97.9	0.1	99.1	0.9
zao	91.7	-3.2	96.2	1.2	94.7	-0.3	93.5	1.9	95.9	1.2
zaq	94.6	3.1	97.2	2.7	95.1	0.5	94.9	0.7	96.9	-0.2
zar	95.6	7.3	88.3	18.0	97.6	1.3	98.8	0.9	99.1	-0.2
zas	97.8	0.7	98.9	0.6	97.9	-0.3	97.2	-1.1	98.7	-0.1
zat	93.4	10.7	95.1	7.2	95.8	8.8	96.0	1.5	98.0	0.6
zav	99.3	0.5	98.6	-2.3	99.0	0.2	98.9	1.2	99.6	0.1
zaw	98.4	0.1	99.0	-1.0	98.0	-1.1	98.2	0.6	99.1	-0.1
zca	96.9	3.7	98.8	0.7	97.0	3.5	95.9	0.4	98.1	2.1
zca	19.9	2.9	58.3	-2.9	32.4	17.9	4.9	80.2	20.6	34.0
zga	90.4	11.9	95.8	1.7	92.6	7.6	90.0	15.2	93.7	8.4
zgh	79.9	-33.5	79.4	-32.0	83.0	-13.1	76.1	-4.3	81.8	-11.5
zhi	89.6	13.1	87.2	21.3	94.2	2.2	90.5	-3.6	94.8	-2.8
zia	98.2	-1.9	99.6	-0.3	98.8	0.2	98.2	2.5	98.9	1.3
zim	97.6	-3.9	99.8	-0.4	99.5	-0.3	99.3	-0.3	99.8	-0.3
ziw	72.9	-17.0	93.1	-4.8	88.6	-4.2	77.3	-10.9	86.6	-9.9
zlm	47.4	0.6	68.0	-4.9	61.9	-3.6	80.2	-7.6	63.8	-16.3
zmb	87.9	3.6	94.9	5.7	80.9	-21.8	85.2	-13.1	86.2	-15.9
zms	99.8	-0.4	99.6	-0.7	99.8	-0.4	99.9	0.2	99.8	0.1
znc	91.1	3.5	96.3	5.2	96.1	2.1	95.2	0.4	97.6	0.5
zoc	98.8	2.1	98.6	1.1	97.1	-2.7	95.6	-6.1	96.4	-5.5
zom	73.8	15.7	85.3	5.4	85.1	11.8	75.0	10.1	81.8	12.8
zos	99.6	0.7	99.5	-0.4	98.9	-1.4	99.4	-0.1	99.6	-0.0
zpc	96.7	-2.8	98.2	-3.3	98.9	-0.1	98.8	0.9	99.5	0.0
zpg	96.5	6.2	98.6	1.3	96.9	2.0	96.2	2.2	98.1	2.5
zpi	96.4	-1.8	98.1	-0.2	96.7	-1.4	95.3	-2.9	97.5	-1.5
zpl	97.9	2.5	98.8	0.8	98.2	0.8	97.7	2.2	98.5	0.0
zpm	98.0	0.9	98.6	0.2	97.0	1.2	96.5	0.9	98.1	1.2
zpo	93.9	3.8	96.4	2.5	97.4	1.4	97.2	2.0	98.4	1.2
zpq	88.2	-20.2	94.3	-10.1	91.8	-13.9	84.4	-25.6	96.5	-5.4
zpi	97.8	-0.4	99.3	-0.4	98.4	-0.7	98.0	1.5	98.9	0.3
zpu	98.7	-0.4	99.5	-0.5	98.9	1.5	98.6	0.1	99.1	0.6
zpv	99.3	0.0	99.4	-0.7	99.4	-0.2	99.2	1.0	99.3	0.8
zpz	98.3	-1.2	99.0	-1.5	99.0	0.7	98.2	-0.3	99.3	0.3
zrs	82.5	-0.5	89.7	9.6	83.6	-0.4	85.1	11.2	87.2	8.0
zsm	42.5	7.2	56.3	11.8	53.6	13.6	45.2	16.8	47.3	22.6
zsr	96.3	-1.4	91.6	-13.3	97.6	-0.2	97.6	0.7	98.8	-0.3
zsg	98.2	1.0	98.9	0.0	98.7	0.2	98.6	0.7	99.3	0.4
zti	97.6	-0.8	99.2	-0.2	98.4	0.4	98.5	0.4	99.1	-0.3
zty	79.2	32.4	88.7	18.3	84.8	22.2	76.5	34.9	94.9	7.3
zui	46.8	-6.7	75.4	-2.6	76.3	-2.8	57.7	13.9	80.0	-2.5
zyb	94.8	3.1	91.2	-7.6	94.7	5.6	93.3	3.0	96.1	4.9
zyp	97.8	0.6	98.4	-1.4	98.0	1.7	95.8	1.2	98.4	1.7

Table 10: Results per language of the model with all 2,034 languages in our benchmarks. We report F1 score, and precision-recall.