Does Synthetic Data Help Named Entity Recognition for Low-Resource Languages?

Anonymous ACL submission

Abstract

In this paper, we explore whether synthetic datasets generated by large language models are useful for low-resource named entity recognition, considering 11 languages from diverse language families. Our results suggest that synthetic data created with seed human labeled data is a reasonable choice when there is no available labeled data, and is better than using automatically labeled data. HOwever, a small amount of high-quality data, coupled with cross-lingual transfer from a related language, always offers better performance.

1 Introduction

Named Entity Recognition (NER) for low-resource languages aims to produce robust systems for languages with limited labeled training data available, and has been an area of increasing interest within natural language processing (NLP). Two common approaches to address this data scarcity are cross-lingual transfer and data augmentation/synthesis; recent research has in particular explored the usefulness of large language models (LLMs) for such data augmentation and synthetic data creation in NLP (Whitehouse et al., 2023; Li et al., 2023), while their use for NER is also emerging (Bogdanov et al., 2024).

In this background, we propose LLM-based synthetic data generation using a small amount of gold examples (Figure 1) as an alternative to relying on automatically created datasets for low-resource NER. With experiments covering 11 languages, we show that

1. Even a small amount of human annotated data can yield far better performance than much larger amounts of synthetic data.
2. Zero-shot transfer from a related language can provide high baselines for low-resource language NER.

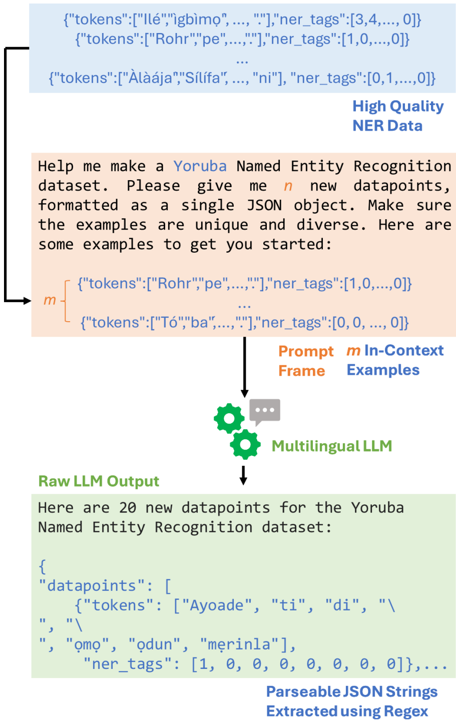


Figure 1: High-level overview of our data generation process. We use multilingual large language models to generate new NER datapoints on the basis of a handful of high quality data points. See Section 3.1 for more.

3. Synthetic data generated by prompting an LLM with a few high quality examples (Figure 1) could be better than using automatically labeled datasets when training low-resource NER models.

We start with a review of related literature (Section 2) and describe our data generation approach and experimental setup in Section 3, followed by a discussion of the results (Section 4), limitations (Section 6) and broader impact (Section 7).

2 Related Work

NER in low resource settings has long been a topic of interest in NLP. Significant research examines cross-lingual transfer from a high resource source language to a lower-resource target language for the task (Rahimi et al., 2019; Mueller et al., 2020; Zeng et al., 2022; Zhao et al., 2022; Yang et al., 2022; Zhou et al., 2022), while other approaches have explored the creation of synthetic datasets through e.g. parallel corpora or machine translation (Mayhew et al., 2017; Ni et al., 2017; Pan et al., 2017; Xie et al., 2018; Liu et al., 2021; Yang et al., 2022; Fetahu et al., 2022).

More recent work has explored using LLMs such as `GPT-3.5` and `GPT-4` as data generators for NER (Bogdanov et al., 2024; Heng et al., 2024). We build on such work, but differ from their methods. Our data generation process uses high quality examples as seeds, and we not only evaluate different LLMs (both open and closed-source), but also experiment with 11 languages covering three language families and five base scripts.

3 Our Approach

At a high level, our approach involves two steps:

1. Using the train split of a high quality (usually manually annotated) NER dataset for a target language to generate synthetic data for that language with the help of an LLM (Section 3.1); and then

2. Comparing the performance of an NER model on the test split of the high quality dataset when trained on synthetic data from Step 1 and another model trained on the train split of the same high quality dataset (Section 3.2).

3.1 Synthetic Data Generation:

Our synthetic data generation process (shown in Figure 1) involves using LLMs to generate new synthetic data points on the basis of existing, high quality NER annotations as described below:

- First, we randomly sample m data points from the train split of an organic (i.e. non-synthetic) NER dataset.

- Next, we format and append these data points to a prompt asking the model to produce n new, unique data points on the basis of the m data points in the prompt.

- We submit this prompt as input to the LLM, and extract any correctly-formatted data points from its response;

- We repeat steps (1)-(3) k times, with each call to the model choosing a different random sample of organic data points.

In our experiments, we set m to 10, n to 20, and k to 500. This sets an upper cap of 5000 synthetic training data points, if every model response contains perfectly formatted data points. We present and solicit data structured as JSON strings to the LLMs, and extract well-formatted samples from model responses using regular expressions. Appendix A provides further details about this process.

We compare three LLMs as our source of synthetic data: `GPT-4`[1] (Achiam et al., 2023), which we assume to be the state of the art; `Llama-3.1-8B-Instruct` (Dubey et al., 2024), as a much smaller, open-source instruction-tuned model; and finally, `aya-expanse-32b` (Dang et al., 2024), as a larger open source multilingual LLM.

3.2 Training NER models:

For all experiments, we use the pre-trained version of `XLM-RoBERTa-large` (Conneau et al., 2020) as our base model and fine-tune it on our synthetic and organic training sets in two distinct settings.

1. In the first setting, we use our data to train an NER model from scratch, by fine-tuning the pre-trained `XLM-RoBERTa-large` on target language NER data.

2. In the second setting, we first fine-tune the model on the high quality NER data in a language *related* source language[2], and then further fine-tune this NER model on our synthetic or organic target language data.

While the first setting—which we name NER FROM SCRATCH—aims to shed light on the relative utility of synthetic data for training an NER model (largely) from the ground up, the latter —which we name NER FINE-TUNING—simulates a common setting, when a lower resource language lacks adequate NER data, but is related to a higher-resource language with existing NER systems. In both settings, we modulate the amount of data (both synthetic and organic) used, so as to compare model performance when trained on smaller or larger amounts of each type of data.

[1] We use `gpt-4-turbo`, and all data generation with the model was conducted between September and December 2024.

[2] See Table 2 in Appendix B for the full list of chosen related languages for all the target languages.

Languages & Datasets: We focus on 11 languages from diverse language families: Tamil, Kannada, Malayalam, Telugu (Dravidian), Kinyarwanda, Swahili, Igbo, Yoruba (Niger-Congo), Swedish, Danish and Slovak (Indo-European). Of these, Igbo, Yoruba, and Kinyarwanda are not among the 100 languages in the `XLM-Roberta` pre-training corpus. We use the Universal NER dataset (Mayhew et al., 2024) as our high quality, manually annotated dataset for Swedish, Danish and Slovak; MasakhaNER2 (Adelani et al., 2022) for Kinyarwanda, Swahili, Igbo and Yoruba; and the Naamapadam dataset (Mhaske et al., 2023) for Tamil, Kannada, Malayalam and Telugu.

While the first two datasets are completely manually annotated, the train and validation splits of the Naamapadam dataset are constructed using parallel corpora, and thus contain some noise. Nevertheless, we choose it as our organic dataset, as (i) its test sets, which contain 500-1000 datapoints per language, are completely manually annotated, and (ii) it remains the largest NER resource for these four languages. Crucially, all of these datasets cover largely identical NER categories, allowing for comparisons between them.

Additionally, we compare models trained on LLM-generated data with those trained using WikiANN (Pan et al., 2017; Rahimi et al., 2019), a large, automatically created NER dataset based on Wikipedia cross-linking, as it covers the 11 languages we study. This dataset represents a different form of synthetic data—one generated not from LLMs, but instead from scraping knowledge bases. Although the dataset has no manual annotations, it is frequently used as a standard low-resource NER benchmark (Schmidt et al., 2022; Asai et al., 2024).

4 Results

4.1 Synthetic Data Generation

We generate the synthetic datasets following the process described in Section 3.1. While model responses from `GPT-4` are almost always usable, we found recurring errors in responses from the other two models. Some of these errors are described in Table 1 in Appendix A; we discard such instances when compiling our synthetic datasets from model responses. The average percentage of usable training datapoints from `GPT-4`, `Llama-3.1` and `aya-expanse` are 97%, 59.3% and 11.7% respectively.[3] We assess the overall quality and viability of this synthetic data by measuring the performance of an NER model on a high quality, manually-annotated test set, when trained on the synthetic data.

4.2 Training on Synthetic Data

Figure 2 shows our results when using synthetic data from different models, in both the NER FROM SCRATCH and NER FINE-TUNING settings. While the models trained on organic data in the NER FROM SCRATCH setting always perform better than synthetic data based models, we find that models trained on `GPT-4`-generated data come the closest to models trained on organic data. We also find that more synthetic data is not necessarily useful; for some languages, we see a saturation after about 1000 data points, and for some, we also notice a drop in performance with more data.

Perhaps more surprisingly, in the NER FINE-TUNING setting, we notice that zero-shot transfer from a related language outperforms the same models after they have been further fine-tuned on synthetic target language data. This suggests that in some cases where an NER model for a related language exists, synthetic data in target languages may actually be detrimental to overall performance.

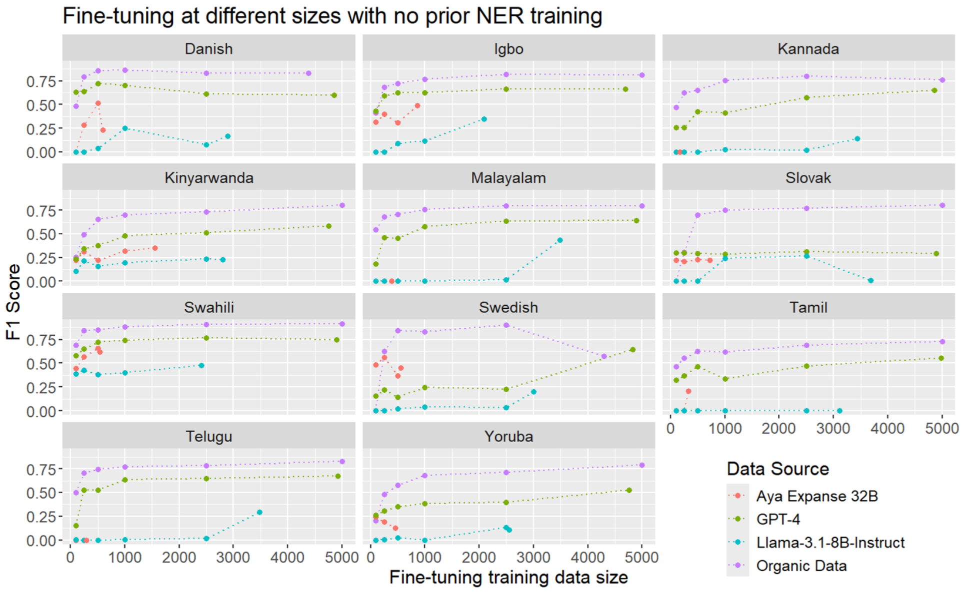
Comparison with WikiAnn: In most cases, when dataset size is comparable, training on WikiANN data in the NER FROM SCRATCH setting yielded NER models that perform considerably worse than those trained on synthetic data from `GPT-4`. For the four Niger-Congo languages, `GPT-4` generated data gave superior results even in the NER FINE-TUNING SETTING (see Table 3 in Appendix C for the detailed results).

5 Conclusions and Discussion

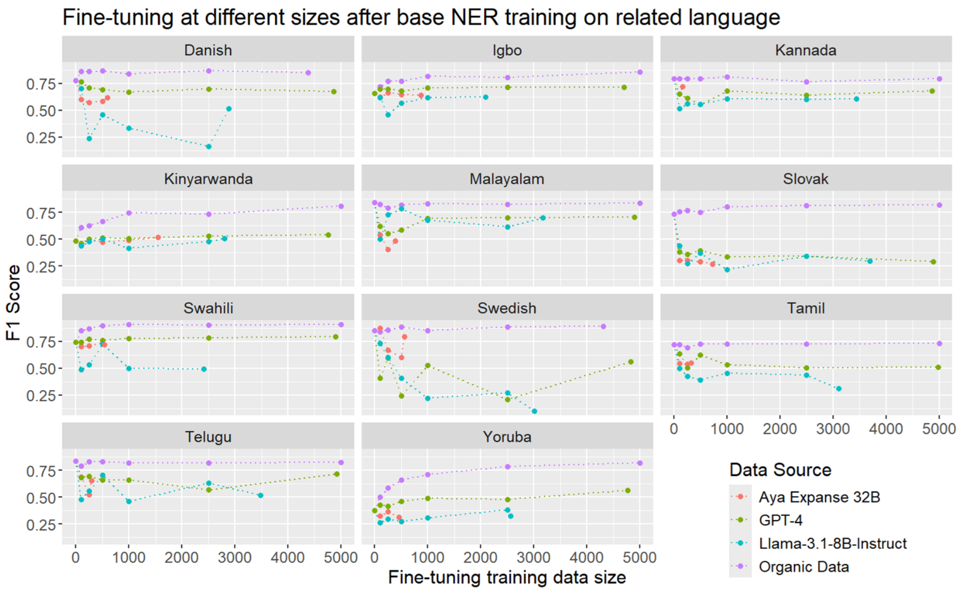
Our results lead us to three main conclusions around the utility of LLM-generated synthetic data for low resource language NER.

1. A small amount of carefully annotated data yields better performance than a large amount of synthetic data. As is evident in Figure 2, even 100 manually annotated data points can yield NER models that cannot be matched by models trained on much larger amounts of synthetic data.

[3] Llama-3.1's rejected datapoints are often incomplete due to hitting new token limits, suggesting potentially higher capabilities under higher token limits.



(a) NER FROM SCRATCH Setting



(b) NER FINE-TUNING Setting

Figure 2: NER model performance when trained on increasingly large subsets of training data. `aya-expanse-32b` and `Llama-3.1-8B-Instruct` produced lower amounts of usable data; this is why they do not extend as far as organic or `GPT-4`-produced data in fine-tuning data size. Performance at `Fine-tuning Dataset Size = 0`, only present in the NER FINE-TUNING setting, indicates zero-shot performance of a related-language NER model.

2. In many cases, zero-shot transfer from a related-language NER model is a high baseline, and that further training such a model on synthetic data may even lower the performance.

3. Despite the fact that it falls short of manually annotated data, LLM-generated data often still yields better model performance than WikiANN, especially for the more low-resource languages among the ones we studied. This echoes the findings by Lignos et al. (2022), who arrive at similarly negative findings around the data quality of WikiANN.

Overall, while showing how synthetic data from LLMs can help train NER models from scratch for low resource languages, our results reinforce the need for manually annotated gold test sets in benchmarking NER for lower resource languages.

6 Limitations

Although we experimented with many languages, the nature of the NER datasets used is relatively simple, containing only three or four entity categories (persons, locations, organizations and dates). Thus, we don't know if the general conclusions, especially about the quality of synthetic data, will extend to scenarios where there are many entity categories. While we did study datasets covering more than one language family, the selection of language is far from extensive, and is also constrained by the availability of human labeled test data. Finally, to keep the experiments under control, we explored a limited set of methods for fine-tuning and synthetic data generation. Our findings should be viewed after taking these aspects into consideration.

7 Ethics and Broader Impact

We used publicly available datasets with human-annotated and automatically labeled data, and also created synthetically generated datasets as a part of this work. The models built using such artificially created datasets should always be validated with a human-labeled data. We did not involve any human participants in this study. All the code and generated datasets is provided at this github repository to support reproducible research: `https://anonymous.4open.science/r/low-resource-syn-ner-A1C7/`.

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LLM Response Quality	Examples
Well-Formatted	{"data": [{ "tokens": ["Lars", "Løkke", "Rasmussen", "besøgte", "firmaet", "i", "Odense", "."], "ner_tags": [1, 2, 2, 0, 0, 0, 5, 0]}, ...
Unequal Token & Tag Lengths	{"id": "4123", "tokens": ["Wananchi", "wamekunja", "mashitaka", "."], "ner_tags": [0, 0, 0, 0, 0, 0]}
Run-On & Incomplete Data	{"id": "9000", "tokens": ["Olorun", "lẹ̀ẹ̀", ..., "ò", "ò", "ò", "ò", "ò", "ò", "ò", "ò", "ò", "ò", "ò", "ò", "ò" {"id":"4617","tokens":["Ọ́ḍǹ", "ọ̀sè", "lè", "ọ̀rị́", "-", "èdè", "Ọ́ḅf́emi", "àfú", "fùn", "àwọn", "gb", "."] "ner_tags":[8,0,0,0,0
Empty Responses & Prompt Continuations	<EOS_TOKEN> <EOS_TOKEN>include a mix of names, locations, organizations...

Table 1: Examples of different types of responses from the synthetic data-generating LLMs tested.

A Synthetic Data Generation

As shown in Figure 1, we present the following prompt to the LLM in the data generation process:

```
Help me make a {language} Named Entity Recognition dataset. Please give me {n} new datapoints, formatted as a single JSON object. Make sure the examples are unique and diverse. Here are some examples to get you started:
{m examples}
```

For GPT-4, we used the OpenAI API's functionalities for structured outputs to ensure that outputs were formatted as JSON strings. For the open-sourced models, we experimented with using transformers-compatible libraries for obtaining structured outputs from LLMs, but ultimately found better results simply specifying the JSON requirement in the model and system prompt. For the open-sourced models, we used the following system prompt:

```
You are a helpful model that helps build text-based datasets, but does not produce any conversation besides the text it is asked to produce. You only output JSON strings.
```

For GPT-4, we used the following (minimally different) system prompt, on the assumption that specifying output mode in the system prompt was less important on account of the API's structured output functionalities:

```
You are a helpful model that helps build text-based datasets, but does not produce any conversation besides the text it is asked to produce.
```

We ran all open-sourced models using vLLM (Kwon et al., 2023), with a temperature setting of 0.8, maximum new token limit of 4096 new tokens, and nucleus sampling value of 0.8. Calls to GPT-4 were made using default hyperparameters.

Table 1 shows some of the examples of the different types of responses to these prompts.

B Related-Language Model Details

In the NER FINE-TUNING setting, we first train an NER model on a language related to the target language, before fine-tuning it further on the target language NER data. Below is the list of related languages chosen to build a base NER model for each target language.

Target Language	Related Language Chosen
Kannada	Telugu
Tamil	Telugu
Telugu	Kannada
Malayalam	Tamil
Kinyarwanda	Swahili
Swahili	Kinyarwanda
Yoruba	Igbo
Igbo	Yoruba
Swedish	Danish
Danish	Swedish
Slovak	English*

Table 2: List of related languages used in the NER FINE-TUNING setting for each target language. *English is not closely related to Slovak, but given the absence of another highly related language among the 11 target languages, it was chosen as the language for the base NER model to be fine-tuned.

B.1 NER-fine tuning: Implementation Details

We source the pre-trained XLM-RoBERTa-large weights from Huggingface using the transformers library; fine-tuning is implemented using training pipelines from the same library. In the NER FROM SCRATCH setting, we train on the the target language data for 10 epochs; in the NER FINE-TUNING setting, we train on the related language data for 5 epochs, and then the target language data for 10 epochs. In all cases, we use a learning rate of 2e-05, and a batch size of 16.

C Full Results of WikiANN Comparison

The WikiANN dataset is a massively multilingual NER benchmark, comprising data from 176 languages (Pan et al., 2017; Rahimi et al., 2019).[4] Table 3 shows the full list of comparisons between NER model performance when trained on organic data, GPT-4-produced data, and WikiANN data. The sizes of the WikiANN train sets vary significantly between different languages, meaning we often cannot assess the quality of the data in the context of training sets containing over 1000 datapoints (e.g. Kannada and Yoruba, whose WikiANN train sets contain only 100 datapoints). In such cases, however, we compare model performance when trained on equally small amounts of organic or LLM-produced synthetic data.

Language		N.F.S. F1	N.F.T. F1	Data Size
Kannada	WikiANN	4.5e-3	0.77	100
	GPT-4	0.26	0.65	100
	GPT-4	0.65	0.68	4861
	Naamapadam	0.47	0.79	100
	Naamapadam	**0.76**	**0.79**	5000
Telugu	WikiANN	0.67	0.74	1000
	GPT-4	0.64	0.66	1000
	GPT-4	0.67	0.72	4919
	Naamapadam	0.77	0.82	1000
	Naamapadam	**0.83**	**0.82**	5000
Tamil	WikiANN	0.55	0.62	15000
	GPT-4	0.56	0.51	4977
	Naamapadam	**0.73**	**0.73**	5000
Malayalam	WikiANN	0.65	0.74	10000
	GPT-4	0.64	0.70	4898
	Naamapadam	**0.79**	**0.83**	5000
Yoruba	WikiANN	0.07	0.21	100
	GPT-4	0.26	0.43	100
	GPT-4	0.53	0.56	4761
	MasakhaNER 2	0.20	0.50	100
	MasakhaNER 2	**0.79**	**0.82**	5000
Swahili	WikiANN	0.50	0.59	1000
	GPT-4	0.74	0.78	1000
	GPT-4	0.75	0.79	4900
	MasakhaNER 2	0.69	0.85	1000
	MasakhaNER 2	**0.92**	**0.90**	5000
Kinyarwanda	WikiANN	7.9e-4	0.35	100
	GPT-4	0.23	0.46	100
	GPT-4	0.58	0.54	4754
	MasakhaNER 2	0.26	0.61	100
	MasakhaNER 2	**0.80**	**0.81**	5000
Igbo	WikiANN	7.7e-3	0.39	100
	GPT-4	0.43	0.70	100
	GPT-4	0.66	0.71	4693
	MasakhaNER 2	0.41	0.72	100
	MasakhaNER 2	**0.81**	**0.86**	5000
Danish	WikiANN	0.72	0.71	20000
	GPT-4	0.60	0.68	4857
	Universal NER	**0.83**	**0.85**	4383
Swedish	WikiANN	0.36	0.29	20000
	GPT-4	0.65	0.56	4825
	Universal NER	0.58	**0.89**	4303
Slovak	WikiANN	0.57	0.55	20000
	GPT-4	0.29	0.29	4889
	Universal NER	**0.80**	**0.82**	5000

Table 3: Performance of NER models trained on WikiANN, synthetic data from GPT-4, and high quality 'organic' data, for all 11 languages. N.F.S: NER FROM SCRATCH setting; N.F.T: NER FINE-TUNING setting.

[4]As Lignos et al. (2022) also note, strictly speaking, the original version of WikiANN put together by Pan et al. (2017) contains data from 282 languages; the version of the dataset commonly downloaded from Huggingface, however, and put together by Rahimi et al. (2019), contains data from 176 languages. In this work, we refer to the latter when referring to the WikiANN dataset.