Analysis of Transfer Learning for Named Entity Recognition in South-Slavic Languages

Nikola Ivačič [1]
Hanh Thi Hong Tran[1,2,3]
Boshko Koloski[1,2]
Senja Pollak[1]
[1]Jožef Stefan Institute,
[2]Jožef Stefan IPS,
1000 Ljubljana, Slovenia

Matthew Purver[1,4]
[3] University of La Rochelle
17000 La Rochelle, France
[4]School of Electronic Engineering
and Computer Science
Queen Mary University of London
London E1 4NS, UK

Abstract

This paper focuses on Named Entity Recognition for South-Slavic languages using pre-trained multilingual neural network models. We investigate whether the performance of the models for a target language can be improved by using data from closely related languages. The results show that this is not the case for the Slovene language, while for Croatian and Serbian, the results are better in selected cross-lingual settings. The most significant performance improvement is observed for the Serbian language, which has the smallest corpora, showing the potential of the method in less-resourced settings.

1 Introduction

Named Entity Recognition (NER) is one of the cornerstones of the NLP tasks and is widely used in many real-life applications, including in the news industry. In our study, we focus on South-Slavic languages and investigate whether the performance of the models for a target language can be improved by using data from closely related languages.

The research on NER has a long history. Already in the 90s, the research was performed by Grishman and Sundheim (1996), followed by Sang and De Meulder (2003); Segura-Bedmar et al. (2013), to mention a few of the early works. Early literature focused on rule-based models (Yu et al., 2020), which were based on a set of pre-defined patterns, and hand-crafted rules (e.g., LTG, NetOwl). These approaches were followed by the unsupervised methods (Collins and Singer, 1999; Nadeau et al., 2006), where no annotated data were required. The advent of machine learning algorithms opened a novel direction for NER tasks where feature engineering gained more traction (Krishnan and Manning, 2006; Mansouri et al., 2008; Liu et al., 2020). With recent advances in neural networks, NER was formulated as a sequence-labelling task and took advantage of the neural systems, especially Transformers, to minimize the effort of feature engineering (Lample et al., 2016; Tran et al., 2021). Ensemble systems that combine different machine learning (Ekbal and Saha, 2011; Saha and Ekbal, 2013) and neural representation (Tran et al., 2021) or architectures (Chiu and Nichols, 2016; Liu et al., 2018) were also under consideration. Besides rich-resourced languages (e.g., English), there is a shift to several less-resourced ones, including the Slavic family (see several organized shared tasks Piskorski et al. (2017, 2019, 2021)).

The availability of multilingual large language models and transfer learning strategies (Devlin et al., 2019) have simplified the cross-lingual transfer for a variety of NLP tasks. This opened new opportunities in the development of multilingual applications, especially in settings with limited resources. Cross-lingual learning allows for overcoming the problems with the lack of data, including in zero- and few-shot learning, where no or very small number of data for the target language is available. Moreover, getting the performance of a multilingual neural model as close as possible to the performance of a monolingual one can be very beneficial also in terms of simplicity and scalability, as a single model can be used instead of many monolingual ones. Last but not least, even if data for the target language is available, adding data in other languages can lead to an improvement in results.

Multilingual models have been used in a large number of tasks, including cross-lingual hate-speech detection (Pelicon et al., 2021b), zero-shot sentiment analysis (Pelicon et al., 2021a) as well as for NER (Arkhipov et al., 2019; Suppa and Jariabka, 2021). It was shown that the multilingual BERT transformer model outperforms the BiLSTM-CRF model for the NER task. The performance can be even further improved with a word-level CRF layer (Arkhipov et al., 2019). Nevertheless, it is also evident that XLM-Roberta outper-

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Table 1: List of Used Corpora, which shows each corpus with an abbreviated name used in this paper, followed by the number of sentences, the number of tokens it contains, and lastly, its long name.

Corpus	Sentences	Tokens	Long Name
		Slovene	
bsnlp	18106	400291	BSNLP 2017/21 (Piskorski et al., 2021)
500k	9483	193611	ssj500k 2.3 (Krek et al., 2021)
ewsd	2024	31233	ELEXIS-WSD 1.0 (Martelli et al., 2022)
scr	18139	391526	SentiCoref 1.0 (Žitnik, 2019)
		Croatian	
bsnlp	820	18704	BSNLP 2017 and 2021 (Piskorski et al., 2021)
500k	24780	504227	hr500k 1.0 (Ljubešić et al., 2018)
		Serbian	
set	3891	86726	SETimes.SR 1.0 (Batanović et al., 2018)
		Bosnian	
wann	8917	199378	WikiANN / PAN-X (Rahimi et al., 2019)
		Macedonian	
wann	16227	156467	WikiANN / PAN-X (Rahimi et al., 2019)

forms BERT (Suppa and Jariabka, 2021) in such tasks. The closest to our paper is the work by Prelevikj and Zitnik (2021), who showed that the monolingual NER model performance for the Slovene language is practically equal to that of a multilingual one.

In our paper, we focus on NER in Slovene, Croatian and Serbian and aim to answer the following question: does fine-tuning with related languages influence the performance of a multilingual model compared to fine-tuning only in the target language?

The rest of the paper is structured as follows. First, we present the corpora we used and how we preprocessed them, followed by their analysis. Next, we continue with presenting the methodology, where we first introduce the measures, models, hyper-parameters, and software used. Finally, we continue by evaluating the results and by presenting conclusions.

2 Data Description

In this section, we first present all the corpora used. Then, we continue with the description of the conversion of these datasets to the expected format and conclude with the corpora structure analysis.

We used the most common and established NER corpora for selected languages (see Table 1). The assumption and strategy for gathering corpora were also: "the more, the better."

We used NER tags in IOB2 (Ramshaw and Marcus, 1995) format from the CoNLL-2003 shared task (Tjong Kim Sang and De Meulder, 2003) as a common denominator for all corpora and experiments. Each corpus was first combined if split, then converted to a common format, reshuffled, and split to train/validation/test set in an 80/10/10 ratio.

We produced combined corpora by concatenating the sets without further reshuffling so that the experiments could be repeated.

Our study uses Slovene, Croatian, and Serbian as target languages. However, in addition to those, also Bosnian and Macedonian are considered as the source languages, as they are closely related.

Corpora used are presented in Table 1. Note that the ones for Slovene were obtained from BSNLP and parts of a newly published combined Training corpus SUK 1.0 (Arhar Holdt et al., 2022), which contained NER annotations (ssj500k, ELEXIS-WSD, and SentiCoref).

2.1 Data Conversion

The first obstacle was the different NER tags used in corpora. We decided to keep only the common tags: PER, LOC, and ORG. For example, the BSNLP corpus uses PRO and EVT tags, while the *wann* corpus lacks a MISC tag common to 500k training corpora. All non-common tags, including MISC, were replaced with O (outside IOB).

The second obstacle was the difference in format. BSNLP corpus, for instance, uses separate files for verbatim text and NER tags, with no positional reference between one another. We used CLASSLA (Ljubešić and Dobrovoljc, 2019) sentence segmentation and tokenization with a custom conversion script to solve this problem.

In addition, we removed a small amount (54) of very short sentences, as they were often noisy (e.g. conversion errors).

Next, we converted corpora from standard CoNLL format to CSV format with two fields:

- Sentence: whitespace separated sentence word tokens.
- NER: white space separated NER tags for each sentence word token.

Table 2: Example whitespace separated sentence word tokens with corresponding IOB2 NER tags.

Obtoženka	Asia	Bibi	zapustila	Pakistan
O	B-PER	I-PER	O	B-LOC

Finally, we split the corpus data into train, validation, and test sets.

2.2 Corpora analysis

Comparing the corpora showed the differences that could potentially be problematic for obtaining aligned model performance. Especially considering the NER tag ratios where the WikiANN automatically annotated corpora structure was standing out (see Table 3 and Figure 1). This is also one of the reasons why in our experiments, WikiANN corpora were only considered for additional training but not as target language gold standards.

Table 3: Analysis of Combined Corpora - shows each language's combined corpora number of tokens per sentence, followed by the number of NER tags per token. Finally, the PER, LOC, and ORG columns show the ratios with respect to all NER tags.

Lang.	tok./sent.	NER/tok.	PER%	LOC %	ORG %
sl	21.29	9.09%	31.70%	22.20%	34.13%
hr	20.43	7.41%	28.71%	20.55%	30.82%
sr	22.29	12.01%	29.96%	30.12%	32.35%
bs	**7.81**	**36.91%**	31.65%	29.67%	38.67%
mk	**9.64**	**28.07%**	34.89%	30.32%	34.79%

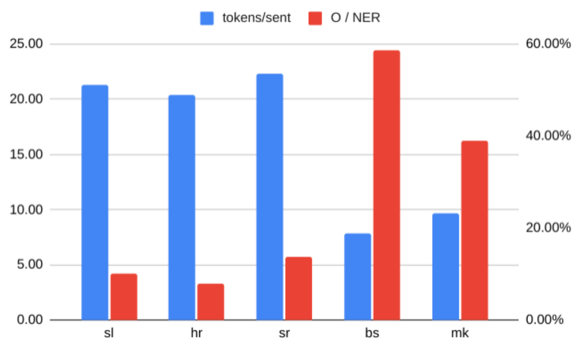

Figure 1: WikiANN corpus skew

Fortunately, we were unable to detect any inconsistencies regarding performance measurements.

3 Methodology

In the following section, we present the methodology used in our experiments to test our hypothesis that the NER classification F1-score increases when we fine-tune the pre-trained multilingual model with an additional, related language.

3.1 Method

The selected method was first to select the pre-trained embeddings, train the baseline model for each language and produce NER classification measurements. Baseline models were fine-tuned with only one - target language.

We experimented with two multilingual models, BERT multilingual base model (cased) (Devlin et al., 2018) and XLM-RoBERTa (base-sized model) (Conneau et al., 2019). However, pilot results showed better performance of XLM-RoBERTa, which was used in the final experiments presented in this paper.

Next, we combined additional language corpora, re-trained the model, and measured performance on the target language test set again. We focus only on three selected languages for evaluation, Slovene, Croatian and Serbian, but consider Bosnian and Macedonian as additional source languages.

We used the HuggingFace transformers Python library (Wolf et al., 2020) for all the experiments.

3.2 Parameters

For all the experiments, we used the following hyper-parameters:

- 256 max-length for tokenizer
- PyTorch's AdamW algorithm with 5e-5 learning rate
- batch size of 20
- 40 epochs (preliminary runs showed best F1-scores between epochs 15 and 35)
- F1-score for best model selection and training progression.

4 Evaluation

In the following section, we define the F1-score we used for evaluation. Then we present the experiment results: the evaluation of the pre-trained multilingual model, followed by the evaluation of fine-tuning for each language.

For all classification measurements, the Seqeval library (Nakayama, 2018) was used. Although the library uses CoNLL evaluation by default, we chose "strict" mode evaluation. When calculating measurements, the strict mode also considers the IOB2 tag's "beginning" and "inside" parts. Therefore the NER tags must match exactly.

4.1 Evaluation measure

For the evaluation of the classification models, we used the traditional F-measure or balanced F-score, which is the harmonic mean of precision and recall:

$$\text{F1-score} = 2 \cdot \frac{Precision \cdot Recall}{Precision + Recall}$$

The Precision and Recall are defined as:

$$\text{Precision} = \frac{TP}{TP + FP} \qquad \text{Recall} = \frac{TP}{TP + FN}$$

given that:

- FP: a NER tag that is predicted but not present in the test.
- FN: a NER tag present in the test but missing in our prediction.
- TP: a NER tag that is correctly predicted.

The overall F1-score, used in the evaluation tables and figures, is a macro-averaged F1-score over all three NER tags. Macro-averaged F1-score is computed using the arithmetic mean of all the per-class F1 scores:

$$\text{Macro-averaged F1-score} = \frac{1}{n} \sum_{i=1}^{n} F1_i$$

where $F1_i$ is the F1-score for ith NER tag.

The average distance from the baseline was used as a measure to show the overall variability of different models tested with the same test set. We also report the maximum reduction in error rate achieved for each tag.

4.2 Results

Here, we present results for the three target languages.

4.2.1 Slovene

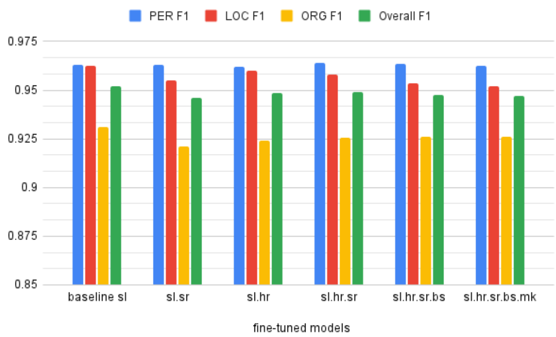

Figure 2: Slovene language test set model performance

The Slovene test set shows surprising model stability. This stability comes, assumingly, from larger corpora compared to the others. It might be that the quality of the corpora also plays a crucial role in this observation.

Table 4: Slovene language test set model performance

Model	PER F1	LOC F1	ORG F1	Overall F1
baseline sl	0.963	**0.963**	**0.931**	**0.952**
sl.sr	0.963	0.955	0.921	0.946
sl.hr	0.962	0.960	0.924	0.948
sl.hr.sr	**0.964**	0.958	0.925	0.949
sl.hr.sr.bs	**0.964**	0.953	0.926	0.948
sl.hr.sr.bs.mk	0.962	0.952	0.926	0.947
avg. dist.	0.00071	0.0070	0.0063	0.0043
error reduction	2.7%	-	-	-

If we observe the average distance from the baseline in the table's last row, we can see that it is only near 0.5%. For the PER tag, the error rate is reduced by a small amount (2.7%), but other tags are not improved.

4.2.2 Croatian

The Croatian language test set shows higher variability when tested with different models, most significantly on the ORG tag. It might be that the other corpora training is influencing variability. However, there is now some overall performance gain from the training: we can see that the average distance from the baseline is 0.5-1%, with reductions in error rates between 6 and 11%.

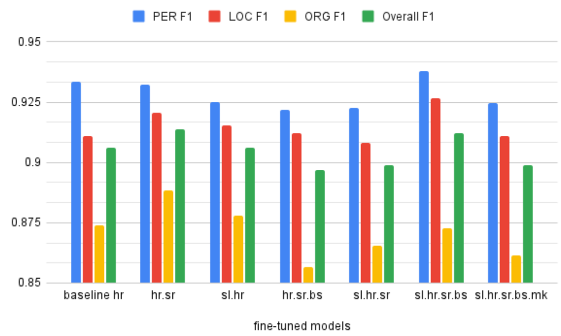

Figure 3: Croatian language test set model performance

Table 5: Croatian language test set model performance

Model	PER F1	LOC F1	ORG F1	Overall F1
baseline hr	0.934	0.911	0.874	0.906
hr.sr	0.932	0.921	**0.888**	**0.914**
sl.hr	0.925	0.915	0.878	0.906
hr.sr.bs	0.922	0.912	0.856	0.897
sl.hr.sr	0.923	0.908	0.865	0.899
sl.hr.sr.bs	**0.938**	**0.927**	0.873	0.912
sl.hr.sr.bs.mk	0.925	0.911	0.861	0.899
avg. dist.	0.0076	0.0055	0.0098	0.0062
error reduction	6.1%	18.0%	11.1%	8.5%

4.2.3 Serbian

The Serbian language test set showed the most significant increase in performance over the baseline. Its average distance in performance measurements from the baseline is from approximately 0.5% to 2.5%, with large reductions in error rate of 43%-68%. The main suspect for this phenomenon is the Serbian corpus size. It is the smallest included in this analysis, and therefore benefits most from additional cross-lingual training on other corpora.

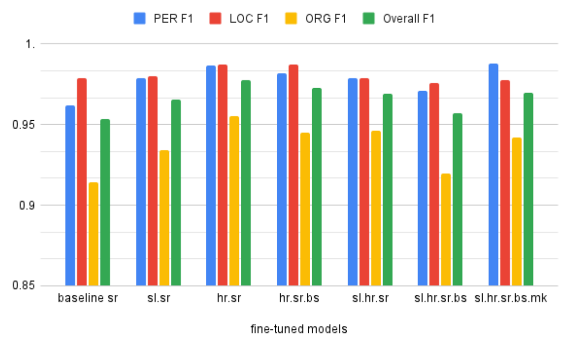

Figure 4: Serbian language test set model performance

Table 6: Serbian language test set model performance

Model	PER F1	LOC F1	ORG F1	Overall F1
baseline sr	0.962	0.979	0.914	0.954
sl.sr	0.979	0.980	0.934	0.965
hr.sr	0.987	**0.988**	**0.956**	**0.978**
hr.sr.bs	0.982	0.987	0.945	0.973
sl.hr.sr	0.979	0.979	0.946	0.969
sl.hr.sr.bs	0.971	0.976	0.920	0.957
sl.hr.sr.bs.mk	**0.988**	0.978	0.942	0.970
avg. dist.	0.019	0.0037	0.026	0.015
error reduction	68.4%	42.9%	48.8%	52.2%

5 Conclusion

We have shown that model performance can be influenced substantially by cross-lingual training with other language corpora, but that improvements only seem to occur if the target language has relatively small corpora. While for Slovene, the monolingual setting generally performs better, for Croatian and Serbian, the results are slightly better in selected cross-lingual settings. The most significant performance improvement is shown for the Serbian language, which has the smallest corpora. This indicates that fine-tuning with other closely related languages may benefit only the "low resource" languages.

Our initial hypothesis has not been fully upheld, but the result is still beneficial. First, when considering less-resourced settings, leveraging closely related languages is beneficial. Second, the performance does not degrade much if we fine-tune the model with additional language corpora from the same family. This is an important finding, as using a multilingual model in an application is a simpler solution than having several monolingual models.

In future work, we propose further investigating how performance changes when distantly related languages are used for fine-tuning the models. This will further benefit the usage in an industrial setting if the performance is not degraded, as having a single model that supports more languages with similar performance to monolingual training is more scalable and practical.

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