

# The LMU Munich System for the WMT 2020 Unsupervised Machine Translation Shared Task

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## Abstract

This paper describes the submission of LMU Munich to the WMT 2020 unsupervised shared task, in two language directions, German↔Upper Sorbian. Our core unsupervised neural machine translation (UNMT) system follows the strategy of Chronopoulou et al. (2020), using a monolingual pretrained language generation model (on German) and fine-tuning it on both German and Upper Sorbian, before initializing a UNMT model, which is trained with online backtranslation. Pseudo-parallel data obtained from an unsupervised statistical machine translation (USMT) system is used to fine-tune the UNMT model. We also apply BPE-Dropout to the low-resource (Upper Sorbian) data to obtain a more robust system. We additionally experiment with residual adapters and find them useful in the Upper Sorbian→German direction. We explore sampling during backtranslation and curriculum learning to use SMT translations in a more principled way. Finally, we ensemble our best-performing systems and reach a BLEU score of 32.4 on German→Upper Sorbian and 35.2 on Upper Sorbian→German.

## 1 Introduction

Neural machine translation achieves remarkable results (Bahdanau et al., 2015; Vaswani et al., 2017) when large parallel training corpora are available. However, such corpora are only available for a limited number of languages. UNMT addresses this issue by using monolingual data only (Artetxe et al., 2018c; Lample et al., 2018). The performance of UNMT models is further improved using transfer learning from a pretrained cross-lingual model (Lample and Conneau, 2019; Song et al., 2019). However, pretraining also demands large monolingual corpora for both languages. Without abundant data, UNMT methods are often ineffective (Guzmán et al., 2019). Therefore, effectively trans-

lating between a high-resource and a low-resource language, in terms of monolingual data, which is the target of this year’s unsupervised shared task, is challenging.

We participate in the WMT 2020 unsupervised machine translation shared task. The task includes two directions: German→Upper Sorbian (De→Hsb) and Upper Sorbian→German (Hsb→De). Our systems are constrained, using only the provided Hsb monolingual data and De NewsCrawl monolingual data released for WMT. We pretrain a monolingual encoder-decoder model on a language generation task with the Masked Sequence to Sequence model (MASS) (Song et al., 2019) and fine-tune it on both languages of interest, following Chronopoulou et al. (2020). We then train it on UNMT, using online backtranslation. We use our USMT system to backtranslate monolingual data in both languages. This pseudo-parallel corpus serves to fine-tune our UNMT model. Iterative offline backtranslation is later leveraged, yielding a performance boost. We use BPE-Dropout (Provilkov et al., 2020) as a data augmentation technique, sampling instead of greedy decoding in online backtranslation, and curriculum learning to best include the SMT pseudo-parallel data. We also use residual adapters (Houlsby et al., 2019) to translate to the low-resource language (Hsb).

**Results Summary.** The ensemble of our best-performing systems yields the best performance in terms of BLEU<sup>1</sup> among the participants of the unsupervised machine translation shared task. We release the code and our best models<sup>2</sup> in order to facilitate reproduction of our work and experimentation in this field. We note that we have built upon

<sup>1</sup>[http://matrix.statmt.org/matrix/systems\\_list/1920](http://matrix.statmt.org/matrix/systems_list/1920)

<sup>2</sup><https://github.com/alexandra-chron/umt-lmu-wmt2020>

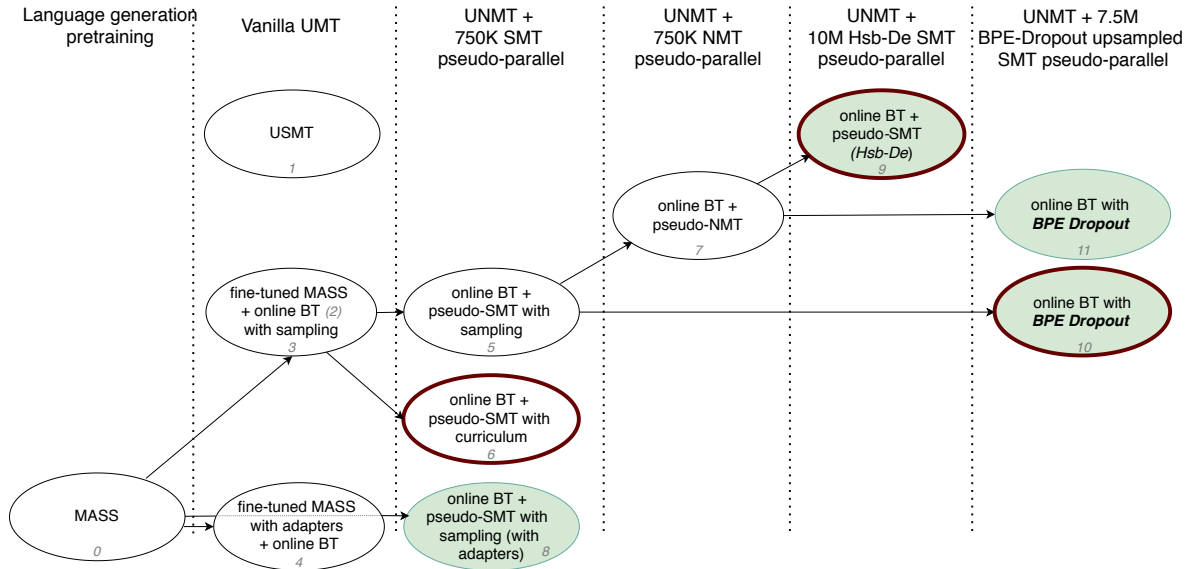


Figure 1: Illustration of our system. We denote with green the systems that were ensembled for the De→Hsb direction and with maroon the systems that were ensembled for the Hsb→De direction. Right arrows indicate transfer of weights. The numbers in gray correspond to the rows of Table 1. Online BT refers to the backtranslation of sentences with the actual model and updating it with the generated pseudo-parallel data. Pseudo-SMT refers to data obtained by backtranslating using the USMT baseline system while pseudo-NMT to our translations using system 5. The components of our approach are explained in Section 2.

the MASS codebase<sup>3</sup> for our experiments.

## 2 Model Description

Figure 1 presents all the different components of our system and how they are connected to each other. We train both an unsupervised SMT (#1) and NMT (#2) model. The UNMT model is based on a pretrained MASS model (#0), which is *monolingual* (De). The model is later fine-tuned on both Hsb and De. We additionally explore fine-tuning only on Hsb using adapters. These models are used to initialize an NMT model (#2, #4) which is trained with online backtranslation. We additionally experiment with sampling (#3) during backtranslation. The USMT model is used to backtranslate Hsb and De data. This synthetic bi-text is used to fine-tune the baseline UNMT model (#5). We use the synthetic bi-text also to fine-tune directly the adapter-augmented MASS model, while employing online backtranslation and sampling (#8). We experiment with curriculum learning (#6) to estimate the optimal way to feed the model this pseudo-parallel data. We also use our UNMT model to generate backtranslations and fine-tune existing models (#7). Further USMT-backtranslated data is used in #9. Finally, some models are fine-tuned with monolingual data which is oversampled and segmented

<sup>3</sup><https://github.com/microsoft/MASS>

with BPE-Dropout (#10, #11). The details of these components are outlined in the following.

### 2.1 Unsupervised SMT

First we describe the USMT system which we use to generate pseudo-parallel data to fine-tune our NMT system. We use *monoses* (Artetxe et al., 2018b), which builds unsupervised bilingual word embeddings (BWEs) and integrates them to Moses (Koehn et al., 2006), but apply some modifications to it.

As a first step, we build unsupervised BWEs with *fastText* (Bojanowski et al., 2017) and *VecMap* (Artetxe et al., 2018a) containing representations of 1-, 2- and 3-grams. Since the size of the available monolingual Hsb data is low, mapping monolingual embeddings to BWEs without any bilingual signal fails, i.e., we find no meaningful translations by manually investigating the most similar cross-lingual pairs of a few words. Instead, we rely on identical words occurring in both De and Hsb corpora as the initial seed dictionary. The BWEs are then converted to phrase-tables using cosine similarity of words and a language model is trained on the available monolingual data. The shared task organizers released a validation set which we use to tune the parameters of the system with MERT, instead of running unsupervised tuning as described in Artetxe et al. (2018b). Finally, we run 4 itera-

tive refinement steps to further improve the system. Other than the above, all steps and parameters are unchanged.

We use this system in inference mode to back-translate 7M  $D_e$  and 750K  $H_{sb}$  sentences. We refer to this pseudo-parallel dataset as `7.7M SMT pseudo-parallel`. We also backtranslate 10M more  $D_e$  sentences. This dataset is later used to fine-tune one of our systems. We refer to it as `10M Hsb-De SMT pseudo-parallel`.

## 2.2 MASS

We initialize our UNMT systems with an encoder-decoder Transformer (Vaswani et al., 2017), which is pretrained using the MASS (Song et al., 2019) objective. The model is pretrained by trying to reconstruct a sentence fragment given the remaining part of the sentence. The encoder takes a randomly masked fragment as input, while the decoder tries to predict the masked fragment. MASS is inspired by BERT (Devlin et al., 2019), but is more suitable for machine translation, as it pre-trains the encoder-decoder and the attention mechanism, whereas BERT is an encoder Transformer. In order to pretrain the model, instead of training MASS on both  $D_e$  and  $H_{sb}$ , we initially train it on  $D_e$ . After this, we fine-tune it on both  $D_e$  and  $H_{sb}$ , following RE-LM (Chronopoulou et al., 2020). The intuition behind this is that, if we simultaneously train a cross-lingual model on unbalanced data, where  $X$  is much larger than  $Y$ , the model starts to overfit the low-resource side  $Y$  before being trained on all the high-resource language data ( $X$ ). This results in poor translations. We refer to our pretrained model as FINE-TUNED MASS.

### 2.2.1 Vocabulary Extension for NMT

To fine-tune the pretrained  $D_e$  MASS model on  $H_{sb}$ , we need to overcome the following issue: the pretrained model uses BPE segmentation and vocabulary based only on  $D_e$ . To this end, we again follow RE-LM. We denote these BPE tokens as  $BPE_{D_e}$  and the resulting vocabulary as  $V_{D_e}$ . We aim to fine-tune the monolingual MASS model to  $H_{sb}$ . Splitting  $H_{sb}$  with  $BPE_{D_e}$  would result in heavy segmentation of  $H_{sb}$  words. To prevent this from happening, we learn BPEs on the joint  $D_e$  and  $H_{sb}$  corpus ( $BPE_{joint}$ ). We then use  $BPE_{joint}$  tokens to split the  $H_{sb}$  data, resulting in a vocabulary  $V_{H_{sb}}$ . This method increases the number of shared tokens and enables cross-lingual transfer of the pretrained model. The final vocabulary is the union

of the  $V_{D_e}$  and  $V_{H_{sb}}$  vocabularies. We extend the input and output embedding layer to account for the new vocabulary items. The new parameters are then learned during fine-tuning.

## 2.3 Adapters

Besides initializing our UNMT systems with FINE-TUNED MASS, we also experiment with pretraining MASS on  $D_e$  and fine-tuning *only* on  $H_{sb}$ . During fine-tuning, we freeze the encoder and decoder Transformer layers and add adapters (Houlsby et al., 2019) to each of the Transformer layers. Adapters can prevent catastrophic forgetting (Goodfellow et al., 2013) and show promising results in various tasks (Bapna and Firat, 2019; Artetxe et al., 2020). We fine-tune only the output layer, the embeddings and the decoder’s attention to the encoder as well as the lightweight adapter layers.

We investigate adapters as fine-tuning in this way is considerably more computationally efficient. We also experimented with freezing the decoder’s attention to the encoder as well as adding an adapter on top of it, but these architecture designs are worse in terms of perplexity during MASS fine-tuning as well as BLEU scores during UNMT.

We use the fine-tuned model to initialize an encoder-decoder Transformer, augmented with adapters. The adapter-augmented model is then trained in an unsupervised way, using online back-translation. All layers are trainable during unsupervised NMT training. We refer to this model as FINE-TUNED MASS + ADAPTERS.

## 2.4 Unsupervised NMT (online backtranslation)

We initialize our UNMT models with FINE-TUNED MASS. Following Song et al. (2019), we train the systems in an unsupervised manner, using online backtranslation (Sennrich et al., 2016a) of the monolingual  $H_{sb}$  and  $D_e$  data, that were also used for pretraining. As proposed in Song et al. (2019), we do not use denoising auto-encoding (Vincent et al., 2008). We use online backtranslation to generate pseudo bilingual data for training. We refer to the resulting model as UNMT BASELINE.

## 2.5 Sampling

We experiment with sampling instead of greedy decoding during online backtranslation. Edunov et al. (2018) show that sampling is beneficial for backtranslation compared to greedy decoding or beam search for systems trained on larger amounts

of parallel data. Although we do not use any parallel data, we assumed that our initial UNMT baseline is of reasonable quality and that sampling would be beneficial. However, in order to provide a balance, we randomly use either greedy decoding or sampling during training. The frequency with which sampling is used is a hyperparameter which we set to 0.5. Sampling temperature is set to 0.95.

## 2.6 Curriculum learning

Considering the high improvements achieved by including SMT backtranslated data, we conduct experiments to determine a more meaningful way to feed the data to the model using curriculum learning (Kocmi and Bojar, 2017; Platanios et al., 2019; Zhang et al., 2019). We learn the curriculum using Bayesian Optimization (BO) for which we use an open source implementation<sup>4</sup>. Similar work has been proposed for transfer learning (Ruder and Plank, 2017) and NMT (Wang et al., 2020). As we already have a reasonably trained NMT model, we use it to compute instance-level features for learning the curriculum. Each sentence pair from the SMT backtranslated data is represented with two features: the model scores for this pair in the *original* (backtranslation  $\rightarrow$  monolingual sentence) and *reverse* direction (monolingual  $\rightarrow$  backtranslation).

The weights that determine the importance of these features are learned separately for  $De \rightarrow Hsb$  and  $Hsb \rightarrow De$ , so that we have 4 features in total. BO runs for 30 trials. The feature weights are constrained in the range  $[-1, 1]$ . Each trial runs 5.4K NMT updates. The curriculum optimizes the sum of  $Hsb \rightarrow De$  and  $De \rightarrow Hsb$  validation perplexity. For the optimization trials, we only use the SMT backtranslated data as pseudo-parallel data and do not use online backtranslation. Finally, based on the feature weights and the features for each sentence, we sort the pseudo-parallel data and fine-tune the UNMT BASELINE with SMT backtranslations and online backtranslation. It would be interesting to study if a similar approach can be used to estimate a more optimal loading of monolingual data during MASS pretraining and UNMT.

## 2.7 Offline Iterative Backtranslation

We also experiment with creating synthetic training data using offline backtranslation with one of our UNMT systems (#5 in Table 1). We translate 750K  $De$  sentences to  $Hsb$  and 750K  $Hsb$  sen-

<sup>4</sup><https://ax.dev/>

tences to  $De$ . The resulting pseudo-parallel system is denoted as `750K NMT pseudo-parallel corpus` and is used to fine-tune the same system.

## 2.8 BPE-Dropout

BPE segmentation is useful in machine translation, as it efficiently addresses the open vocabulary problem. This approach keeps the most frequent words intact and splits the rare ones into multiple tokens. It builds a vocabulary of subwords and a merge table, specifying which subwords have to be merged and the priority of the merges. BPE segmentation always splits a word deterministically. Introducing stochasticity to the algorithm (Provilkov et al., 2020), by simply removing a merge from the merges with a pre-defined probability  $p$ , results in significant BLEU improvements for various languages in low- and medium-resource datasets.

We use BPE-Dropout in the following way: we oversample the `Hsb` monolingual data by a factor of 10 and apply BPE-Dropout. In that way, we get different segmentations of the same sentences and feed this data to the model. We also oversample the `750K SMT pseudo-parallel corpus` in the same manner, but only apply BPE-Dropout to the `Hsb` side. These monolingual and pseudo-parallel oversampled datasets are used to fine-tune our models. These systems perform better than our other single systems.

## 2.9 Ensembling

For the final models, we perform ensemble decoding with the best training models obtained in our experiments. We evaluate several combinations of model ensembles. Based on BLEU scores on the test set provided during development, we decide on two separate ensembles for  $De \rightarrow Hsb$  and  $Hsb \rightarrow De$  for the final submission.

# 3 Experiments

## 3.1 Data Pre-processing

In line with the rules of the WMT 2020 unsupervised shared task<sup>5</sup>, we used 327M sentences from WMT monolingual News Crawl<sup>6</sup> dataset for German, collected over the period of 2007 to 2019. We also used the Upper Sorbian side of the provided parallel data as well as all of the monolingual data, a total amount of 756K sentences, provided by the

<sup>5</sup>[http://www.statmt.org/wmt20/unsup\\_and\\_very\\_low\\_res/](http://www.statmt.org/wmt20/unsup_and_very_low_res/)

<sup>6</sup><http://data.statmt.org/news-crawl/de/>



#	Methods	De→Hsb	Hsb→De
0	MASS	5.6	7.0
1	USMT	19.3	21.4
2	① UNMT baseline (fine-tuned MASS)	24.4	27.1
3	② UNMT baseline + sampling	25.4	27.4
4	① UNMT baseline (fine-tuned MASS with adapters)	18.8	21.7
5	③ + online BT + pseudo-SMT + sampling	29.9	31.9
6	③ + online BT + pseudo-SMT + curriculum	<u>30.0</u>	32.5
6*	③ + online BT + pseudo-SMT + curriculum + sampling	30.2	32.8
7	⑤ + online BT + pseudo-NMT	29.8	<u>33.2</u>
8	① + online BT + pseudo-SMT + sampling (with adapters)	29.0	32.3
9	⑦ + online BT + pseudo-SMT (Hsb-De)	<u>30.0</u>	32.7
Data oversampling with BPE-Dropout			
10	⑤ + BPE-Dropout	30.7	33.4
11	⑦ + BPE-Dropout	<u>31.8</u>	<u>34.0</u>
12	Model Ensemble (8, 9, 10, 11)	<b>32.4</b>	<b>35.2</b>
13	Model Ensemble (6, 9, 11)	31.9	34.8

Table 1: BLEU scores of UMT for De-Hsb and Hsb-De systems. The systems with the underlined results were ensembled and used in our primary submissions. #12 is our primary system submitted to the organizers in the De→Hsb direction, while #13 is our primary system submitted in the Hsb→De direction. 6\* was trained after the shared task and is not used for the final submission.

organizers. We used the provided parallel data for validation/testing (2K/2K sentences). We normalized punctuation, tokenized and true-cased the data using standard scripts from the Moses toolkit (Koehn et al., 2006). We note that we tokenized Hsb data using Czech as the language of tokenization, since these two languages are very closely related and there are no tokenization rules for Hsb in Moses.

We used BPE (Sennrich et al., 2016b) segmentation for our neural system. Specifically, we learned 32K codes and computed the vocabulary using the De data. We then also learned the same amount of BPEs on the joint corpus (De, Hsb) and computed the joint vocabulary. We extended the initial vocabulary, adding to it unseen items. We used this augmented vocabulary to fine-tune the MASS model and run all the UNMT training experiments.

### 3.2 Data Post-processing

We fixed the quotes to be the same as in the source sentences (German-style). We also applied a recaser using Moses (Koehn et al., 2006) to convert the translations to mixed case.

### 3.3 Training

**Unsupervised SMT.** As mentioned before, we used *fastText* (Bojanowski et al., 2017) to build 300 dimensional embeddings on the available monolingual data. We build BWEs with *VecMap* (Artetxe et al., 2018a) using identical words as the seed

dictionary and restricting the vocabulary to the most frequent 200K, 400K and 400K 1-, 2- and 3-grams respectively. We used *monoses* (Artetxe et al., 2018b) as the USMT pipeline but used the available validation data for parameter tuning and ran 4 iterative refinement steps.

**MASS.** We use a Transformer, which consists of 6-layer encoder and 6-layer decoder with 1024 embedding/hidden size, 4096 feed-forward network size and 8 attention heads. We pretrain MASS on De monolingual data, using Adam (Kingma and Ba, 2015) optimizer with inverse square root learning rate scheduling and a learning rate of  $10^{-4}$ . We used a per-GPU batch size of 32. We trained the model for approximately 2 weeks on 8 NVIDIA GTX 1080 Ti 11 GB GPUs. The rest of the hyperparameters follows the original MASS paper. We fine-tune MASS on both De and Hsb using the same setup, but on 4 GPUs of the same type. Fine-tuning was performed for 2 days.

**Unsupervised NMT.** For unsupervised NMT, we further train the fine-tuned MASS using online backtranslation. We use 4 GPUs to train each one of our UNMT models. We report BLEU using SacreBLEU (Post, 2018)<sup>7</sup> on the provided test set. **Unsupervised NMT + Pseudo-parallel MT.** We train our UNMT systems using a pseudo-parallel supervised translation loss, in addition to the online backtranslation objective. We found out that aug-

<sup>7</sup>BLEU+case.mixed+numrefs.1+smooth.exp+tok.13a+version.1.4.13

menting UNMT systems with pseudo-parallel data obtained by USMT leads to major improvements in translation quality, as previous work has showed (Artetxe et al., 2018b; Stojanovski et al., 2019).

## 4 Results

The results of our systems on the test set provided during development are presented in Table 1. Our USMT model (#1) performs competitively, but is largely outperformed by the UNMT baseline (#2). These results are interesting considering that both systems are trained using small amounts of monolingual  $H_{sb}$  data. We believe that the performance of the UNMT model is largely due to the MASS fine-tuning scheme which allowed us to obtain a strong pretrained model for both languages. We also observe (#3) that mixing greedy decoding and sampling during backtranslation is beneficial compared to always using greedy decoding (#2), especially for  $De \rightarrow H_{sb}$  which improved by 1.0 BLEU. However, it is likely that sampling is useful only if the model is of reasonable quality. We note that the adapter-augmented model (#4) is worse than the UNMT baseline.

After these initial experiments, we use the USMT model (#1) to backtranslate all  $H_{sb}$  monolingual data and 7M  $De$  sentences. This pseudo-parallel data is leveraged to fine-tune our UNMT models alongside online backtranslation. This approach, denoted as model #5, improves the UNMT baseline (#3) by more than 5.5 BLEU for  $De \rightarrow H_{sb}$  and 4.5 BLEU for  $H_{sb} \rightarrow De$ . The curriculum learning approach (#6) yields a small improvement of 0.6 BLEU for  $H_{sb} \rightarrow De$ . Unfortunately, the curriculum learning model ran without the use of sampling. We later train the model with sampling (#6\*) and obtain slight improvements in both directions.

Using NMT backtranslations in an offline manner (#7) provides for a large improvement in the  $H_{sb} \rightarrow De$  direction, obtaining 33.2 BLEU. Further training our high scoring model #7 on USMT backtranslations, depicted as model #9, degrades performance on  $H_{sb} \rightarrow De$ . This might indicate that USMT backtranslations alone are not very important for high performance, but simply adding any kind of pseudo-parallel data during training.

The adapter-augmented model with USMT backtranslations (#8) manages to close the gap to the baseline model. Comparing #5 and #8, we can see that the model with adapters is worse by 0.9 BLEU on  $De \rightarrow H_{sb}$ , but better by 0.4 on  $H_{sb} \rightarrow De$ . Due

to time constraints, we train #4 and #8 in parallel and #8 is not fine-tuned from #4. Overall, adapters are a promising research direction as they lead to faster MASS fine-tuning and comparable performance.

We observe considerable improvements using BPE-Dropout. As noted before, we oversample the parallel and  $H_{sb}$  monolingual data and apply BPE-Dropout only on  $H_{sb}$ . We use this data to fine-tune some of our already trained models, specifically #5 and #7 which results in models #10 and #11, respectively. This approach improves the  $H_{sb} \rightarrow De$  direction by up to 1.5 BLEU and up to 1.0 BLEU for  $De \rightarrow H_{sb}$ . System #11 proved to be our best single system in both translation directions. We hypothesize that using BPE-Dropout while simultaneously oversampling the data provides for a data augmentation effect. In future work, it would be interesting to decouple these two steps and measure their effect separately.

Ensembling further boosts performance. Ensemble #12 is used for  $De \rightarrow H_{sb}$  and #13 for  $H_{sb} \rightarrow De$ . We note that while computing ensemble BLEU scores during development, we did not fix the issue with German-style quotes. This resulted in ensemble #13 obtaining better scores on  $H_{sb} \rightarrow De$ . We later fix the quotes issue and find out that ensemble #12 is better on both translation directions and is the best system overall.

## 5 Conclusion

In this paper, we present the LMU Munich system for the WMT 2020 unsupervised shared task for translation between German and Upper Sorbian. Our system is a combination of an SMT and an NMT model trained in an unsupervised way. The UNMT model is trained by fine-tuning a MASS model, according to the recently proposed RE-LM approach. The experiments show that the MASS fine-tuning technique is efficient even if little monolingual data is available for one language and results in a strong UNMT model. We also show that using pseudo-parallel data from USMT and UNMT backtranslations improves performance considerably. Furthermore, we show that oversampling the low-resource Upper Sorbian and applying BPE-Dropout, which can effectively be seen as data augmentation, results in further improvements. Adapters in MASS fine-tuning provided for a balance between performance and computational efficiency. Finally, smaller but noticeable gains are obtained from us-

ing curriculum learning and sampling during decoding in backtranslation.

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