Source sentence ISO
Reference translation: ISO is one of the world's two international standardization organizations.
DBR+PBRM: The two major International Organization for Standardization (ISO is one of the world.
DBR+PBRM+DDP+DS: The International Organization for Standardization (ISO is one of the two in the world.
DDP+NR, DBR+PBRM+DDP+NR: The ISO is one of the two major international standardization organization in the world.

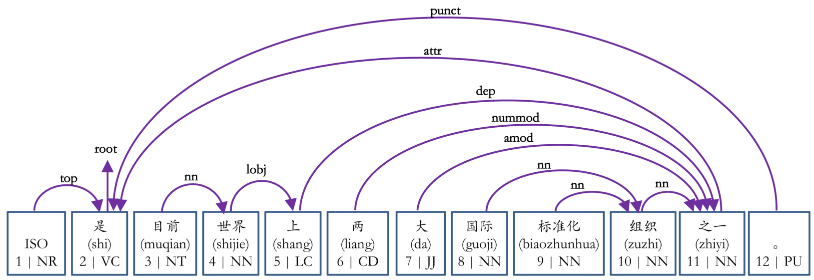

Figure 2: **Left**: a sample sentence and our translation output with distance-based reordering (**DBR**), phrase-based reordering models (**PBRM**), dependency distortion penalty (**DDP**), and sparse dependency swap (**DS**) features, compared to neural reordering in a 10-system ensemble with dependency-driven embeddings (**NR**); **Right**: a source dependency parse tree.

through the dependency parse during beam search. They defined sparse decoding features to encourage or penalize the reordering of two words, based on the POS tag and dependency relation label of each word, but not the words themselves.

Neural reordering models have been applied to re-rank translation candidates generated by the translation decoder. **?** (**?**) introduced a recursive auto-encoder model to represent phrases and determine the phrase orientation probability. **?** (**?**) introduced long short-term memory (LSTM) recurrent neural networks to predict the translation word orientation probability. These approaches did not use dependency parse and they were not applied directly during decoding.

Source dependency parse is also used in the pre-ordering approach, which pre-orders words in a source sentence into target word order and then translates the target-ordered source sentence into the target language. While the pre-ordering step typically utilizes a classifier with feature combinations (**?**; **?**), a neural network can replace the classifier to avoid feature combination. De Gispert, Iglesias, and Byrne (**?**) introduced a feed-forward neural network to pre-order the dependency parse tree nodes (words). However, they did not explore dependency-driven embeddings and model ensemble. **?** (**?**) treat pre-ordering as a traversal on the dependency parse tree, guided by a recurrent neural network. In these approaches, the translation possibility is limited to one target ordering. In contrast, applying a neural reordering model jointly with beam search allows for multiple ordering alternatives and interaction with other models, such as the phrase-based reordering models. We can even build multiple neural models (ensemble) and assign a different weight to each of them to optimize translation quality.

Our neural reordering classifier serves as a decoding feature function in SMT, leveraging the decoding. This is similar to prior work on neural decoding features, i.e., neural language model (**?**) and neural joint model (**?**), a source-augmented language model. However, these features are not about word reordering.

While continuous representation of words is originally defined for words (**?**), we also define continuous representation for POS tags, dependency labels, and indicator features. Extending continuous representation to non-word features is also done in neural dependency parsing (**?**; **?**), which shows better performance by using continuous feature representation over the traditional discrete representation.

Conclusion

We have presented a dependency-based reordering approach for phrase-based SMT, guided by neural classifier predictions. It shows that MT can be improved by a neural network approach by not requiring explicit feature combination and by using dependency-driven continuous word representation. Our experiments also show that our neural reordering approach outperforms our prior reordering approach employing sparse dependency-based features.

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