

A Training and Hyperparameters

We conduct experiments based on the 200-D pre-trained GloVe, the 300-D pre-trained FastText, 300-D randomly initialized word vectors and uncased BERT-base representation respectively. For the SemEval-2018 dataset, we train the domain-specific word embeddings, like (Rotsztein et al., 2018), using GloVe and Fasttext respectively. Our corpus is composed of all the abstracts since 2001 (5.4 million tokens) collected using the API ¹ on arXiv.org and the ACL ARC corpus ² (90 million tokens). We trained the word embeddings for 500 epochs with 60 threads. We use 50-D randomly initialized character embeddings. For the TACRED dataset, we use the same embeddings (300-D GloVe) following (Zhang et al., 2018).

For regularization we apply dropout with $p = 0.5$. The output dimension of character CNN is 100-D. We set LSTM hidden size to 300. We set $\lambda = 1.0$. We employ the ReLU function for nonlinearities. To select better models, we divide the NYT training data into 100 pieces and the training data of SemEval-2018 into four pieces. For the NYT and SemEval-2018 dataset, we use the Adam optimization algorithm to update the model parameters with an initial learning rate of 0.001 and a decay rate of 0.9. For the TACRED dataset, we use Stochastic Gradient Descent with an initial learning rate of 0.3 and a decay rate of 0.9. We use a cutoff of 5.0 for gradient clipping. We conducted experiments on an Intel(R) Xeon(R) CPU E7-4830 v3 @ 2.10GHz (Mem: 976G) and the GPU Tesla K40c.

B Ablation Study

Table 1 shows an ablation study of multi-task training and pipeline training. Two systems denote a fine-tuned NER system and a SwitchNet system. Here we use a BERT model as the NER system. We first compare the multi-task training with different settings. A first observation is that relying on the fine-tuned NER system slightly reduces the final results by 1.72% F1. Although the NER system is enhanced, some entities still hurt the final precision. This is because extracting more entities does not always help the relation extraction subtask and some entities may increase the risk of predicting false positives. The training

process is a multi-stage pipeline and relation candidates are determined by the NER system. We first fine tune the NER system and then predict the label sequence \hat{Y}_{ner} which are also written to disk. Then we train the joint entity and relation extraction model that can use the \hat{Y}_{ner} information. When we replace \hat{Y}_{ner} with the ground truth NER labels, the result is significantly improved (5.03% F1). This means that a high quality label sequence can help improve the final results.

Removing the multi-task training degrades the performance by 0.94% F1. This means that multi-task training benefits the RE subtask from the NER subtask. When we remove the NER system, performance will improve slightly (1.72% F1). Because the global optimization process creates an organism that does not rely on the NER system. Then, we remove the NER system and multi-task training. We first train the NER subtask, then freeze the parameters of shared layer, and then train the RE subtask. The result is reduced by 2.51% F1 because the RE subtask cannot be encoded at the lower layer to interact with the NER subtask. This means that multi-task joint training is critical for subtask interaction. When we do not freeze the lower layer, the result drops significantly. Because when we train the RE subtask, the memory for NER subtask is weakening.

We also apply our training pipeline to BERT, a pre-trained bidirectional transformer that has proven very effective in many NLP tasks. BERT has hundreds of millions parameters and has been trained on large-scale corpus. We fine tune a simple BERT model for TE. Table 2 shows the result. When only using multi-task training, BERT achieves slightly higher results than our GRNN model. The downside is the cost of computation. When we remove the multi-task, NER system and Frozen NER, this model almost forgets all the NER memory, so the RE subtask fails. Model fine-tuning can achieve different functions, which also means that BERT is sensitive to parameter changes.

Figure 1 shows the class-aware prediction result. Figure 1a and 1b denote the model with or without the ground truth NER label when predicting the result. We observe “*place_lived*”, “*nationality*”, “*place_of_death*”, “*contains*” and “*company*” relations are easier to extract. Other relations in the test set are not extracted. This might

¹<https://arxiv.org/help/api/index>

²<http://acl-arc.comp.nus.edu.sg/>

Table 1: SwitchNet setting ablation

| Model | Precision | Recall | F1 |
|-------------------------------------|-----------|--------|-------|
| Two systems + multi-task training | 56.78 | 51.89 | 54.23 |
| + NER label | 61.18 | 57.46 | 59.26 |
| –multi-task | 55.64 | 51.13 | 53.29 |
| –NER system | 60.28 | 52.27 | 55.95 |
| –multi-task, NER system | 50.33 | 56.96 | 53.44 |
| –multi-task, NER system, Frozen NER | 55.88 | 43.29 | 48.78 |

Table 2: BERT model setting ablation

| Model | Precision | Recall | F1 |
|-------------------------------------|-----------|--------|-------|
| Two systems + multi-task training | 51.30 | 54.93 | 53.05 |
| + NER label | 54.89 | 61.01 | 57.79 |
| –multi-task | 50.46 | 54.43 | 52.37 |
| –NER system | 50.68 | 56.20 | 53.30 |
| –multi-task, NER system | 46.46 | 54.93 | 50.34 |
| –multi-task, NER system, Frozen NER | – | – | – |

be caused by the class imbalance problem in the training data. Some sparse relations cannot be fully learned. Comparing Figure 1a and 1b, we observe that providing NER labels enhances the extraction of well-learned relation, while other relations are not obviously improved.

This model has two insights. We incorporate inference and interpretability into the process of model learning. First, we propose to use inference scheme to make it a lifelong learning model. This model is an organism that also deals with multi-task learning. This model can adaptively switch between tasks and continuously optimize model parameters based on historical memory. Second, we present a scheme for extracting informative tokens for relation representation. SwitchNet learns the attention function, and then we can use the distribution of attention to explain the relation classification process in a deep learning model. Multi-task learning is a convenient way to unify two sub-tasks in the learning process.

C Case Study

It is instructive to analyze which words the model is attending for relation representation. We hand-picked some examples in the SemEval-2018 dataset and visualize the attention patterns of these samples.

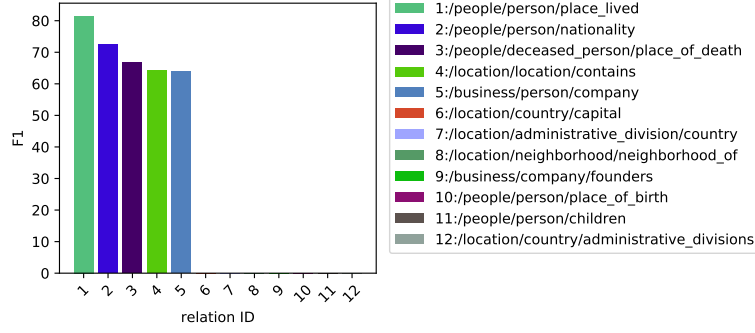
Figure 2 shows how our model extracts informative words for relation representation. The first column is sample id. The second column contains

the extracted triples, and the third column shows the textual input. The underlined phrase represents an entity in the extracted triple. The red degree denotes the word weight for the relation representation. The first sentence shows that this model is capable of focusing on informative words to identify the “*PART-WHOLE*” relation type for “*English-Chinese Bibtexs*” and “*Web*”. The second sentence shows this model resolves the comparative relation by attending to *narrower than*. The third sentence shows that “*are described in*” means the “*TOPIC*” relation.

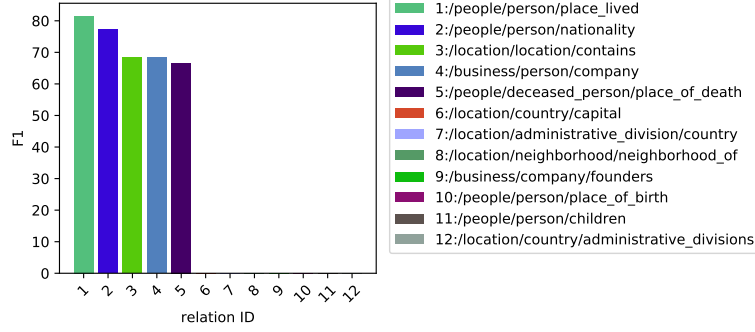
The fourth sentence shows that “*produced by means*” for “*Translations*” and “*beam search decoder*” denotes the “*MODEL-FEATURE*” relation, while the fifth sentence shows this model extracts the relation type “*RESULT*” by attending to “*produce best*”. This suggests that this model considers the entity semantics and sentence context. The sixth sentence shows that this model can extract the informative tokens “*resource for*” instead of the important verb in a long context. These results indicate that the model considers the entity semantics and the relation context while attending to the informative words for relation representation.

D Dataset Overview

Figure 3a shows the relation distribution of the NYT dataset. The x- and y-axes are the relation ID and relation number respectively. We first ob-



(a) Multi-task training



(b) Multi-task training + NER label

Figure 1: Class-aware result

| Id | Triple | Sentences |
|----|--|---|
| 1 | (English-Chinese bitexts, PART_WHOLE, Web) | This piece of work has laid a foundation for exploring and harvesting English-Chinese bitexts in a larger volume from the Web . This piece of work has also laid a foundation for exploring and harvesting English-Chinese bitexts in larger volume from the Web . |
| 2 | (domains, COMPARE, MUC-4 terrorism domain) | These previous domains were much narrower than the MUC-4 terrorism domain . These previous domains were much narrower than the MUC-4 terrorism domain . |
| 3 | (paper, TOPIC, overview) | An overview of HowNet and information structure are described in this paper . An overview of HowNet and information structure are described in this paper . |
| 4 | (beam-search decoder, MODEL-FEATURE, Translations) | Translations are produced by means of a beam-search decoder . Translations are produced by means of a beam-search decoder . |
| 5 | (Bayesian classifiers, RESULT, recall performance) | In our evaluation , Bayesian classifiers produce the best recall performance of 80 % but the precision is low (60%) . In our evaluation , Bayesian classifiers produce the best recall performance of 80 % but the precision is low (60%) . |
| 6 | (WordNet, USAGE, Word Sense Disambiguation (WSD) task) | WordNet has been used extensively as a resource for the Word Sense Disambiguation (WSD) task , both as a sense inventory and a repository of semantic relationships . WordNet has been used extensively as a resource for the Word Sense Disambiguation (WSD) task , both as a sense inventory and a repository of semantic relationships . |

Figure 2: Visualization of some cases

serve there are more than 50,000 “contains” relations while others are less than 9,000. Each relations from 11 to 24 occurs less than 1,000 times. Figure 3b shows that “contains” relation occupies the main part (48.4%), while the relations from 9 to 24 account for 7.7%. This dataset has class

imbalance problem, which poses a challenge to model performance. Figure 3c shows the average distance of each relation type between subject and object. The x- and y-axes are relation ID and token number respectively. We observe that “industry”, “geographic distribution”, “place_of_death” relations are often described in a long context, and “profession”, “neighborhood_of” and “founders” are more likely described in a short context. Figure 3d shows the token number of samples. The x- and y- axes denote the token number and sample number respectively. We observe the average token number is 37.8.

Figure 4a shows the relation distribution of the SemEval-2018 dataset. “USAGE” relation occupies the main part (39.3%). “TOPIC” relation is sparse so it has more impact for the final results. Because the evaluation process uses a macro-averaged F1 score. Although this dataset has less types of relations than NYT dataset, the data sparsity problem poses a challenge to the model. Figure 4c shows the “COMPARE” relationship is more likely described with more words, while the “MODEL-FEATURE” and “PART-WHOLE” relations are more likely expressed with less words. We observe the average distance between subject

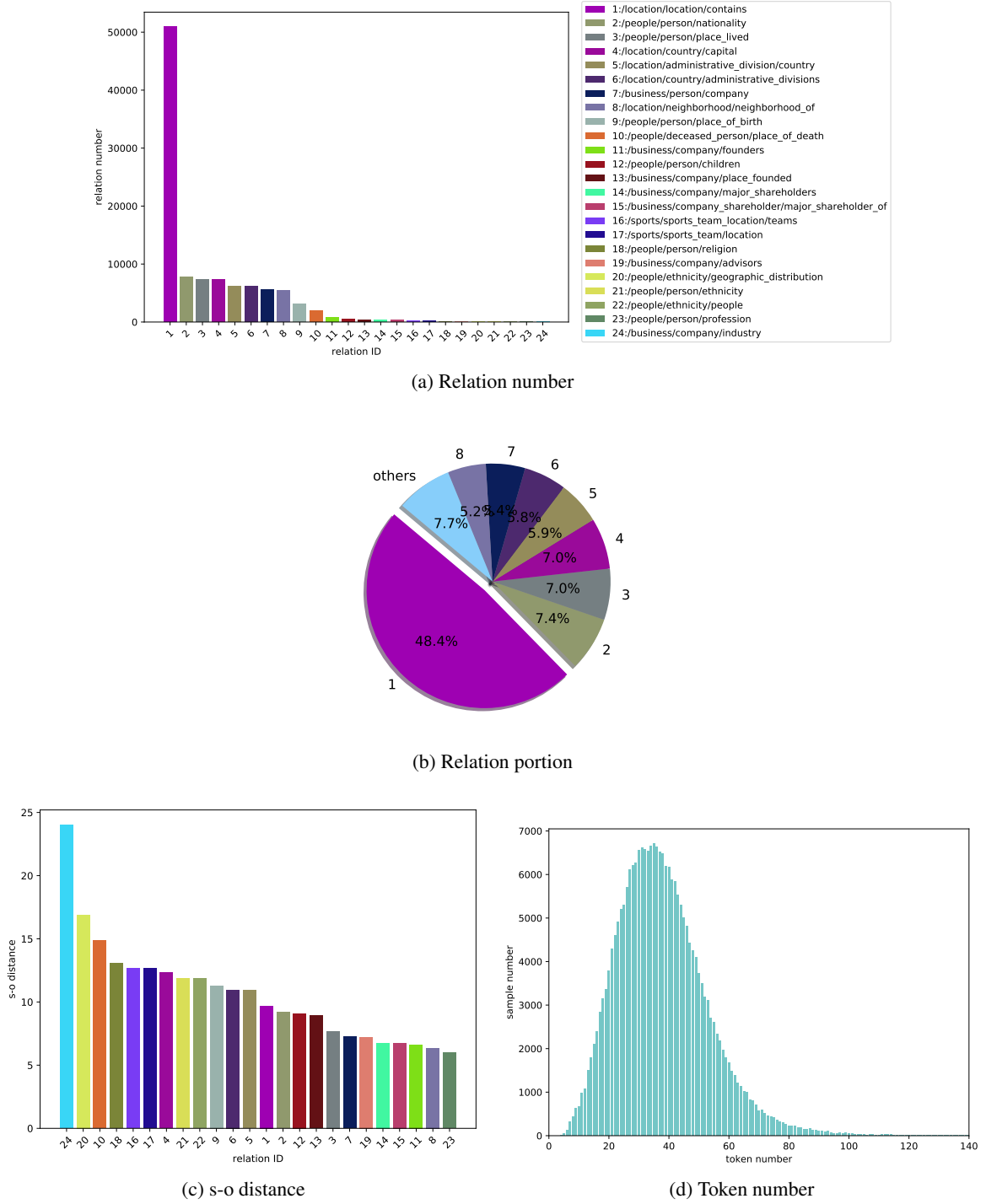
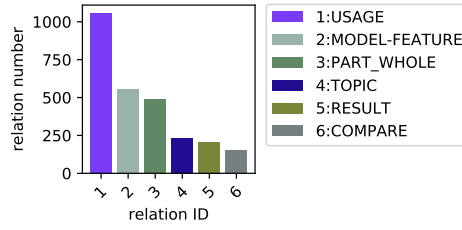


Figure 3: NYT Dataset visualization

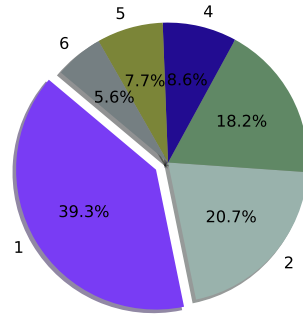
and object entities is also closer than NYT dataset. Figure 4d shows the token number of samples. We observe the average token number is 25.8.

Figure 5a shows the relation distribution of the TACRED. “per:title” relation occupies the main part (17.7%). Figure 5c shows the “per:stateorprovince_of_death” relation is more likely described with more words, while the “org:website” and “org:alternate_names” rela-

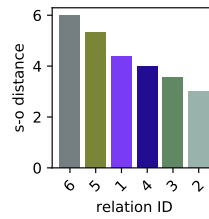
tions are more likely expressed with less words. We observe similar propoerties between NYT and TACRED datasets. For example, they share same relations, i.e., “org:country_of_headquarters” \sim “/location/country/capital”, “/business/person/company” \sim “per:employee_of”. “per:city_of_death” and “/people/deceased_person/place_of_death” both have longer s-o distance. It seems promising to com-



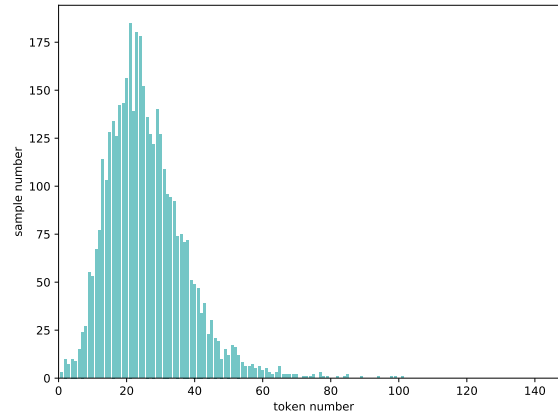
(a) Relation number



(b) Relation portion



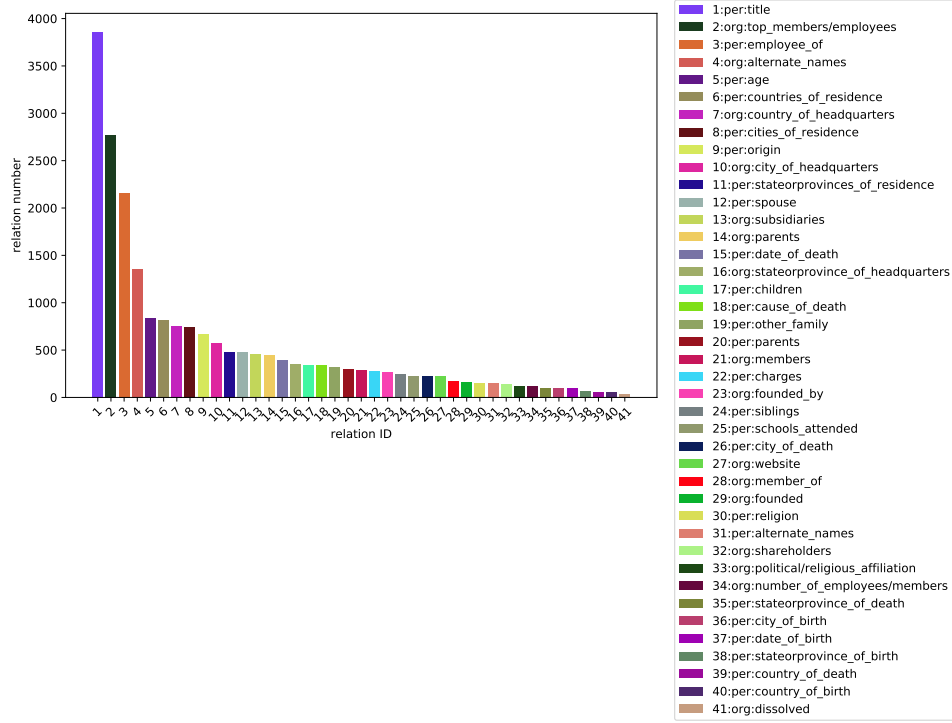
(c) s-o distance



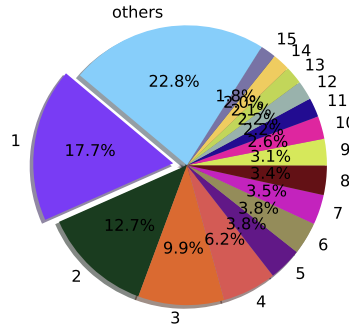
(d) Token number

Figure 4: SemEval-2018 dataset visualization

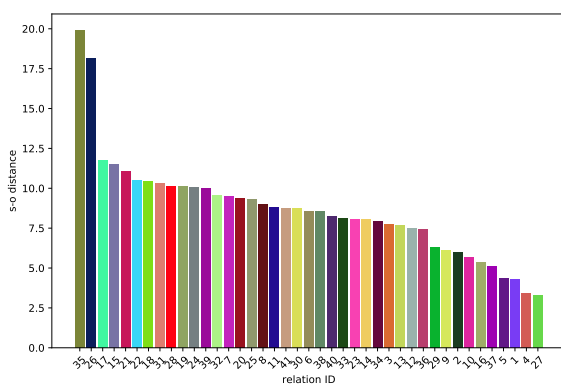
bine the two datasets to address the data sparsity problem. Figure 5d shows the token number of samples. We observe the average token number is 36.4.



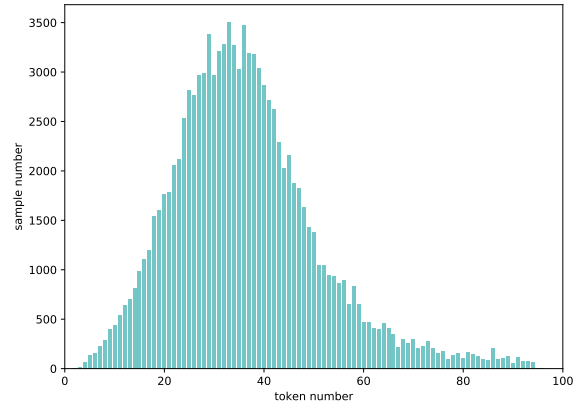
(a) Relation number



(b) Relation portion



(c) s-o distance



(d) Token number

Figure 5: TACRED visualization