Better Semantic Representation: A Low-Shot Relation Extraction Method Based on Token-Generated Contributions

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Abstract

In light of the era of information explosion, traditional relation extraction methods are in a bottleneck due to data limitations in the face of the constant emergence of new relation categories. Therefore the study of low-shot relation extraction in real scenarios is crucial. In the few-shot scenario, it is necessary to build up the model's ability to summarize the semantics of instances. In the zero-shot scenario, it is necessary to establish the label matching ability of the model. Although they need to establish different basic abilities of the model, the common point is that they all need to build excellent semantic representations in the end, which is ignored by the existing methods. In this paper, we propose a method (TGCRE) based on token-generated contribution to unify low-shot relation extraction by generating better semantic representations. Further, we propose a multi-level spatial semantic matching scheme in zero-shot scenarios, aiming to solve the problem that existing methods cannot fully utilize feature information and are susceptible to irrelevant contexts. Experimental results show that our method outperforms previous robust baselines and achieves state-of-the-art performance.

1 Introduction

Relation extraction (RE) is an important basic task in natural language understanding. Traditional relation extraction relying on large-scale high-quality data has achieved excellent performance, but with the development of the times, high-quality data is consumed, and in the face of the emergence of various new relation categories that lack training data, the traditional methods are in a bottleneck.

To cope with this situation, low-shot relation extraction has become a hot research topic. There are two main branches of low-shot relation extraction, namely the study of few-shot RE and zero-shot RE. The few-shot RE requires building the model's ability to summarize the semantics of instances, train the model's learning ability using a few labeled samples per class and quickly generalize it to classify new classes. At present few-shot RE approaches focus on how to summarize better semantic prototypes from a few illustrative examples (Snell et al., 2017; Gao et al., 2019a; Han et al., 2021). Another idea is to augment the FSRE model with knowledge from an external knowledge base (Wen et al., 2021; Qu et al., 2020; Yang et al., 2021). Zero-shot RE requires building the model's ability to match labels. The knowledge transfer capability of the model is trained and generalized to unseen relation categories by the labeled descriptions of the given relations. There are common solution paradigms such as question answering (Levy et al., 2017), textual entailment (Obamuyide and Vlachos, 2018) and semantic matching (Chen and Li, 2021). Despite the advanced performance achieved by semantic matching schemes, there are still some problems, the most representative of which is the single matching pattern, which causes the model to be negatively affected by irrelevant context when matching.

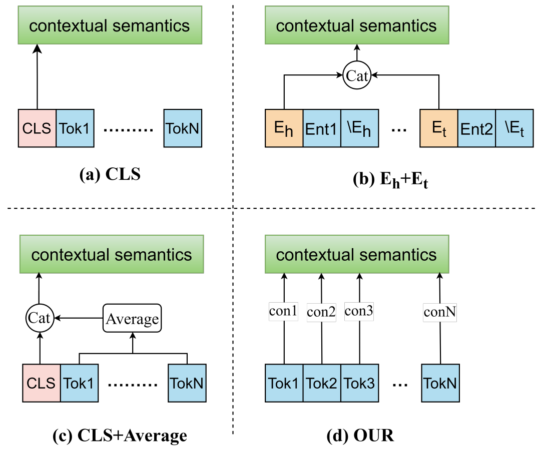

Figure 1: Semantic summarization methods.

Since few-shot and zero-shot RE require the model to build different basic capabilities, current state-of-the-art methods can only be applied and learned to handle one scenario alone. However, what they have in common is that they ultimately need to construct good semantic representations, with few-shot RE requiring the semantic distance between the class prototype representation and its corresponding query instance to be reduced, and zero-shot RE requiring the model to summarize the semantic features of the different relation labels in a focused manner. Obviously, existing methods that simply rely on the semantic summarization ability of special tokens inserted into sentences fail to do this well, because the model does not summarize an optimal semantic representation.

For this reason, we propose the TGCRE method to unify low-shot relation extraction based on their commonalities. The method learns and utilizes the token attributes inherent to each token in a sentence, i.e., it generates a better semantic representation based on the specific contribution each token makes to express the meaning of the sentence. Our and existing contextual semantic summarization methods are shown in Figure 1, it can be seen that our method does not depend on any special token, and the final contextual semantics is completely determined by the specific contribution of the token itself, which has richer semantics and better interpretability than existing methods. See appendix F.1 for detailed analysis. Moreover, in order to solve the problem of a single matching pattern in zero-shot RE, we propose a multi-level spatial semantic matching scheme. Label matching is performed by projecting semantic features to different vector spaces and synthesizing the matching scores from different perspectives. The contributions of this paper are summarized as follows:

1. We develop TGCRE, a low-shot relation extraction method for both zero-shot and few-shot tasks. Experiments demonstrate that our method outperforms previous baselines and achieves state-of-the-art performance in both zero-shot and few-shot tasks.

2. We propose a method for learning token attribute information, based on which a model is guided to understand the magnitude of the contribution of a token, and thus generate a better semantic representation of the context. To the best of our knowledge, we are the first to propose learning and using token attribute information for natural language understanding (NLU) tasks.

3. In the zero-shot RE task, we propose a multi-level spatial semantic matching scheme, which synthesizes the matching scores under multi-angle space to perform semantic matching and greatly improves the accuracy of semantic matching.

2 Related Work

Zero-Shot Relation Extraction. Levy et al. (2017) et al. elucidated for the first time the concept of zero-sample learning for relation extraction by modeling the target task as a question-and-answer problem, and categorizing invisible classes by having the model answer a predefined question template. Obamuyide and Vlachos (2018) et al. modeled the target task as a textual entailment task, which identifies relation categories by determining whether the input sentences entail the corresponding relation descriptions, and fits well with the task definition of zero-sample learning. Sainz et al. (2021) et al. reformulate relation extraction as a problem of entailment, where a linguistic representation of relation labels is used to generate a hypothesis that is confirmed by a ready-made entailment engine. In the latest research, Chen and Li (2021) et al. use different projection functions for input text and relation description text respectively, transform both to the same semantic space, and based on this representation in the space defines relation extraction as a semantic matching task. Zhao et al. (2023a) et al. further proposed a fine-grained semantic matching method to reduce the impact of irrelevant context on matching accuracy. Wang et al. (2022) et al. use contrastive learning to train models that mitigate the prediction errors caused by similar relations and similar entities to the model. Recently, an even more difficult task, Zero-Shot Relation Triplet Extraction (ZSRTE)(Chia et al., 2022; Lv et al., 2023), has been proposed, which requires simultaneous extraction of both entities and relations, which greatly increases the task difficulty and further promotes the research on zero-shot relation extraction.

Few-Shot Relation Extraction. When dealing with few-shot RE tasks, model training and testing are usually performed in a meta-learning manner(Mishra et al., 2017; Huisman et al., 2020; Hospedales et al., 2022). Snell et al. (2017) et al. first proposed the use of prototypical networks for few-shot learning, Han et al. (2018) et al. further proposed a large-scale dataset, FewRel, to study relation extraction methods under few-shot learning. There has been an increase in the number of people involved in few-shot RE research. Gao et al. (2019a) et al. used an attention mechanism to facilitate the generation of better prototype representations from prototype networks. Ye and Ling (2019) et al. used CNN as an encoder and proposed a Multi-Level Matching and Aggregation Network for encoding query instances and class prototypes in an interactive interface. Gao et al. (2019b) et al. present a more challenging dataset, FewRel 2.0, in which they compute the similarity distance between a query instance and all supported instances. Qu et al. (2020) et al. proposed modeling different relations using a global graph approach to obtain prior knowledge between different relations. Han et al. (2021) et al. proposed representation modeling, prototype modeling and task difficulty modeling to solve difficult and simple few-shot extraction tasks. Recently, Liu et al. (2022) et al. proposed a simple direct additive method to introduce relation information, which proved that good relation information introduction is more effective than complex model structure. Li and Qian (2022) et al. proposed a model generation framework GM_GEN to achieve the optimal point on different N-way-K-shot tasks, separating the complexity of all the individual tasks from the complexity of the whole task space.

3 Preliminary

3.1 Token Attribution

For any given sentence, the tokens in the sentence work together and bear the responsibility of expressing the meaning of the sentence. However, each token makes a different specific contribution to the expression of the meaning of the sentence. For example, in the sentence "*I really like carrots.*", the contribution of "*really*" is obviously lower than that of "*like*". Without "*really*", the sentence can still convey the original meaning, but without "*like*", it is not clear whether I like carrots or hate them. We define this property as token attribution(Zhao et al., 2023b).

The measure of token attribution can be approximated by computing the dot product of the token x_i corresponding to the embedding h_i^I and the gradient $\bigtriangledown_{x_i}$, so that the attributes of all the tokens can be obtained after only one forward-backward computation. This approximation is proposed and applied in the interpretation methods of natural language classification models(Feng et al., 2018; Li et al., 2016; Arras et al., 2016). Thus, the method of measuring token attribution in practice can be formulated as:

$$attr\left(x_i|I\right) = \bigtriangledown_{x_i} \cdot h_i^I \tag{1}$$

4 Methodology

4.1 Model Training

In the training phase, the goal is to learn information about the attributes of tokens so that the model has the ability to understand token contributions like a human. For the different inputs in the zero/few-shot setting, which we collectively refer to as input example *I*, which is encoded by the encoder to get the token embedding containing rich contextual semantics, i.e., $\tilde{I} = \left\{h_1^I, h_2^I, \ldots, h_n^I\right\}$. TGCRE is shown in Figure 2.

Forward-Backward Procedure. In section 3.1, we introduced the first-order approximation for calculating token attribution, so we need a forward-backward procedure to obtain the gradient information for each token in the sentence. The backward process is straightforward, what matters is how the forward inference is performed so that tokens with larger contributions have more distinct gradients. We explore different forward inference approaches(See appendix F.2 for detailed analysis) in this paper as follows:

(1) **Mean**: We treat the process of computing the mean of the token embeddings $\tilde{I}$ as forward propagation and the mean as the energy of backward propagation. In this pattern, there is no need to train any parameters other than those of the encoder. The advantage of this method is that it is relatively simple to implement.

$$forward : energy = MA\left(LSE\left(\tilde{I}\right)\right) \tag{2}$$

$$backward : BP\left(energy\right) \tag{3}$$

where $MA\left(\cdot\right)$ represents the mean function, *LSE* is *log-sum-exp* which gives better numerical stability and prevents the data from overflow and underflow problems during computation, and $BP\left(\cdot\right)$ which is the backward propagation of the model to obtain the gradient information.

(2) **Classification**: In order to obtain more reasonable gradient information, we insert a forward-backward procedure based on classification in the forward inference process of the whole method of TGCRE. This is done by training a classification function $cls\left(\cdot\right)$ and applying it to the word embedding $\tilde{I}$ so that the original word vector space is

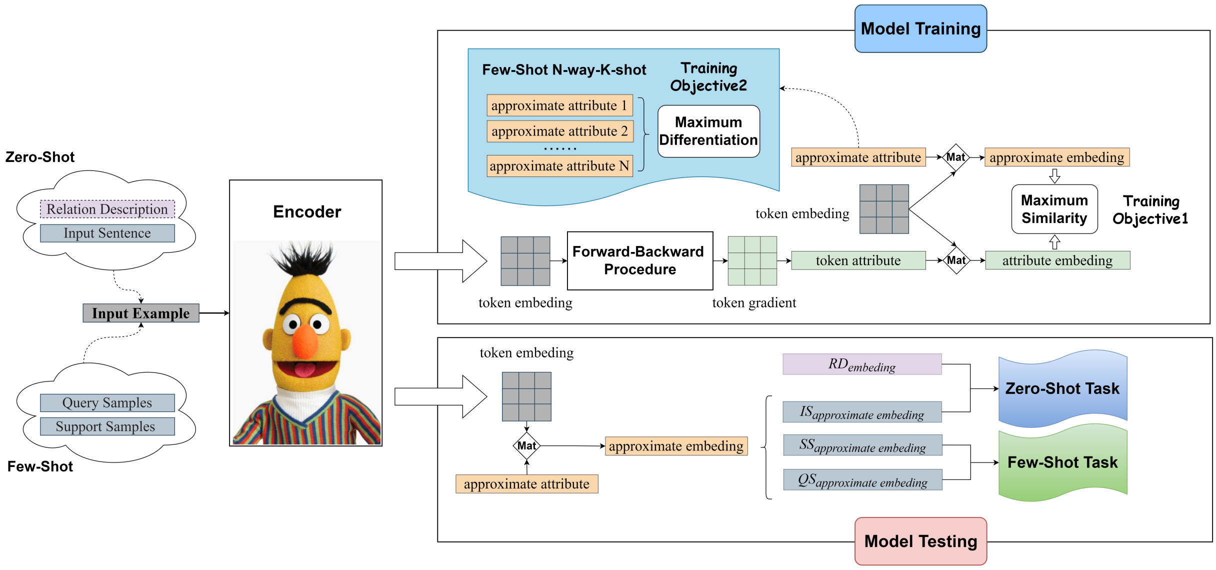

Figure 2: Model overview for TGCRE.

mapped into the relation vector space, obtaining the probability distribution of each relation corresponding to the input instance *I*. The loss is then calculated with the real label to get the energy as backward propagation. Compared to the Mean approach, this approach requires the training of an additional classification function, but the use of a supervised signal *y* allows the model to focus more on meaningful tokens and obtain more reasonable gradient information.

$$forward : energy = CEL\left(cls\left(LSE\left(\tilde{I}\right)\right), y\right) \quad (4)$$

$$backward : BP\left(energy\right) \quad (5)$$

where *y* represents the true label and $CEL\left(\cdot\right)$ represents the cross-entropy loss function, which is used to calculate the gap between the model's predictions and the true values.

Normalization Token Attribution. The gradient information $\bigtriangledown_{x_i}$ of all tokens can be obtained by one forward-backward procedure, which in turn can obtain all word attributes $\left|\bigtriangledown_{x_i} \cdot h_i^I\right|$. In order to visualize the specific degree of contribution of each token, it is necessary to normalize the token attributes to obtain the token attribute vector. The specific operation is shown below:

$$nta\left(x_i\right) = \frac{\left|attr\left(x_i|I\right)\right|}{\sum_{j=1}^{n}\left|attr\left(x_j|I\right)\right|} = \frac{\left|\bigtriangledown_{x_i} \cdot h_i^I\right|}{\sum_{j=1}^{n}\left|\bigtriangledown_{x_j} \cdot h_j^I\right|} \quad (6)$$

where $nta\left(x_1, x_2, \ldots, x_n\right)$ is the normalized token attribute vector.

Training Objective1. For the purpose of utilizing token attribute information and training the model for a deeper understanding of natural language, a generalized approximate attribute vector *apa* that can learn token attribute information is proposed. We take maximizing the similarity between the approximate attribute vector natural language, a generalized approximate attribute vector *apa* and the token attribute vector *nta* as the training goal, so that *apa* is able to learn transferable token attribute knowledge, which in turn effectively guides the model to focus on the contributing tokens in the sentence and generate better semantic representations. First, the features of the token embedding $\tilde{I}$ are summarized based on the token attribute vector *nta*, and the attribute embedding is obtained by highlighting the positively contributing token features and ignoring the negatively contributing token features in the sentence. Secondly, the approximate attribute vector *apa* is also used to summarize the features of token embedding $\tilde{I}$, and approximate embedding is obtained. Finally, we use margin loss to optimize the training objective by iteratively training the model to shrink the similarity distance between attribute embedding and approximate embedding, and to increase the similarity between *apa* and *nta*, so as to continuously optimize the feature summarization ability of *apa*. The process can be formulated as:

$$\mathcal{L}_{sim} = max\left(0, 1 - cos(nta \cdot \tilde{I}, apa \cdot \tilde{I})\right) \quad (7)$$

Training Objective2. In the few-shot setting, we do not use a generalized approximate attribute vector due to the fewer number of relation categories that are restricted during the training process, but instead take the approach of setting a separate approximate attribute vector apa_i for each relation category r_i. To prevent overfitting between the individual approximate attribute vectors, which causes most of the parameters to be invalidated, we introduce the second training objective — maximizing the differentiation between the groups of approximate attribute vectors. First, we compare the similarity between each two vectors apa_i and apa_j, and then accumulate all the similarities to get the overall similarity score of the group of approximate attribute vectors, and use margin loss to reduce the value of the overall similarity score in differentiated training, thus preventing all the approximate attribute vectors from clustering in the same region in the vector space, and realizing the objective of differentiated training. The process can be formulated as:

$$\mathcal{L}_{Dif} = \max\left(0, \frac{\sum_{i=1}^{N}\sum_{j=1}^{N}\cos\left(apa_i, apa_j\right)}{N}\right) \tag{8}$$

4.2 Model Testing

In the testing phase, we use the trained approximate attribute vector *apa* to summarize the token embeddings and obtain the rich contextual semantics of the input examples for the subsequent few-shot RE task and zero-shot RE task. In the few-shot setting, the input examples include support samples and query samples, and the semantic representations after *apa* summarization are $SS_{approximate\ embeding}$ and $QS_{approximate\ embeding}$, respectively. In the zero-shot setting, the input examples consist of input sentence *I* and relation description *d*, where the summarized semantics of the *I* is represented as $IS_{approximate\ embeding}$, while the *d* is encoded using an independently fixed encoder that does not be summarized by the *apa*, and so the encoded semantics is represented as $RD_{embeding}$. It is worth mentioning that the semantic representations of the head and tail entities are extracted in token embeddings, and for the sake of brevity, this process is not shown in Figure 2.

Zero-Shot RE Task. In this paper, we define zero-shot RE as a semantic matching task, and in order to avoid the monotony of matching patterns, we propose a multi-level spatial semantic matching scheme. For the context embedding $IS_{approximate\ embeding}$, head entity embedding $\tilde{e_h^I}$ and tail entity embedding $\tilde{e_t^I}$ of the input sentences in the given original vector space and the context embedding $RD_{embeding}$, head entity embedding $\tilde{e_h^d}$ and tail entity embedding $\tilde{e_t^d}$ of the relation descriptions, we define the embedding set of input sentences $SET_{IS} = \left\{\tilde{e_h^I}, \tilde{e_t^I}, IS_{approximate\ embeding}\right\}$ and the embedding set of relation descriptions $SET_{RD} = \left\{\tilde{e_h^d}, \tilde{e_t^d}, RD_{embeding}\right\}$. After that, we define the left orthogonal transform function $T_l\left(x, w_l\right)$ and the right orthogonal transform function $T_r\left(x, w_r\right)$, through which we can map the embedding set SET_{IS} and the embedding set SET_{RD} into different vector spaces.

$$SET_{IS}^{l} = T_l\left(SET_{IS}, w_l\right) \tag{9}$$

$$SET_{RD}^{l} = T_l\left(SET_{RD}, w_l\right) \tag{10}$$

$$SET_{IS}^{r} = T_r\left(SET_{IS}, w_r\right) \tag{11}$$

$$SET_{RD}^{r} = T_r\left(SET_{RD}, w_r\right) \tag{12}$$

where $w_l \in R^{3\times3}$, $w_r \in R^{h\times h}$ are trainable orthogonal matrices and *h* is the hidden dimension of the encoder. As shown in Figure 3(a), we show a simple schematic of the embedding set transformation, although the real situation is much more complex than this. As can be seen from the figure, after the left (right) orthogonal transformation, SET_{IS} and SET_{RD} in the original space show different poses in different vector spaces, but the relative positions of the vectors in the embedding set are not changed, which ensures that their semantic similarities can be compared from different perspectives without changing the attributes of the original vector set.

We separately compute the semantic matching scores of the SET_{IS} and SET_{RD} in different vector spaces, and the sum of all the matching scores is used as the prediction scores of the input sentence *I* and the relation description *d*.

$$\begin{aligned} p_z(I,d) = \alpha \cdot \cos\left(SET_{IS}^{l}, SET_{RD}^{l}\right) + \alpha \cdot \cos \\ \left(SET_{IS}^{r}, SET_{RD}^{r}\right) + \beta \cdot \cos\left(SET_{IS}, SET_{RD}\right) \end{aligned} \tag{13}$$

where α and β are hyperparameters.

Few-Shot RE Task. In the N-way-K-shot setting, the context embedding is $SS_{approximate\ embeding}$ and $QS_{approximate\ embeding}$ for a given support set *S* and query set *Q* , respectively. We average the context embedding of each class in the support

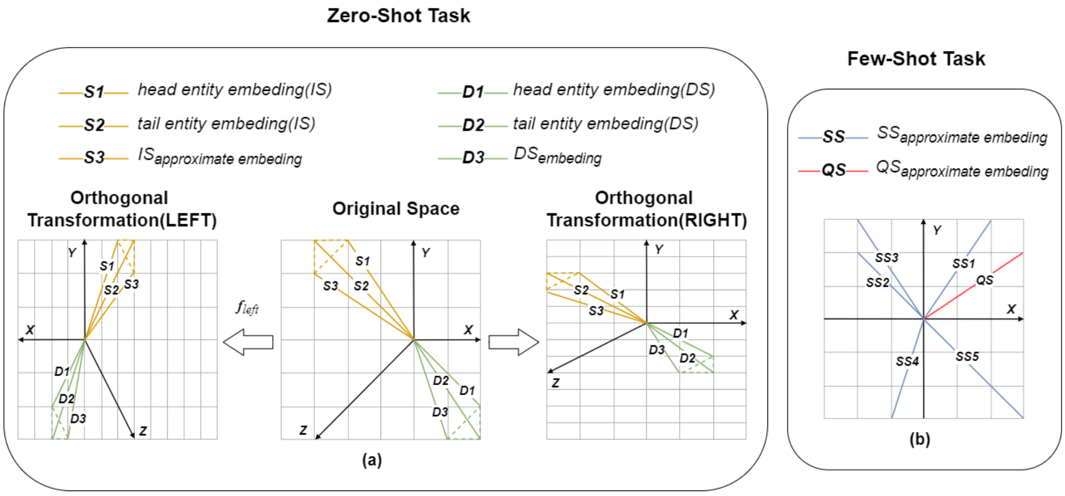

Figure 3: zero/few-shot task.

set S to obtain a prototype representation SS_i for each relation. As shown in Figure 3(b), the prototypical representation of each relation is randomly distributed in the vector space. In this paper, we use the cosine distance as the prediction score of the query instance for each class prototype and use the highest similarity as the final prediction.

$$P_f\left(S, Q\right) = \cos\left(SS_i, QS\right) \tag{14}$$

where QS represents the context embedding $QS_{approximate\ embedding}$ of the query set.

4.3 Loss Function

In the zero-shot setting, in order to prevent the model overconfidence, we randomly sample the negative pairs to constrain the model, assuming that the prediction score of the positive pairs is $p_z\left(I, d_y\right)$, and that of the negative pairs is $p_z^i\left(I, d_i\right)$, then we require that the prediction score of the model's positive pairs is larger than that of the negative pairs, i.e., $p_z\left(I, d_y\right) - p_z^i\left(I, d_i\right) = \varphi > 0$, and the loss term is $\mathcal{L}_{lim} = max\left(0, \gamma - \varphi\right)$, where $\gamma > 0$ is a hyperparameter. To summarize, the total loss of the zero-shot RE is:

$$\mathcal{L}_z = \mathcal{L}_{sim} + \mathcal{L}_{lim} \tag{15}$$

In the few-shot setting, we use a cross-entropy loss function to optimize the gap between the model's prediction and the label, with a loss term of $\mathcal{L}_{cel} = CEL\left(p, y\right)$, where p is the model's prediction and y is the true label. To summarize, the total loss of the few-shot RE is:

$$\mathcal{L}_f = \mathcal{L}_{sim} + \mathcal{L}_{dif} + \mathcal{L}_{cel} \tag{16}$$

5 Experiments

In this section, we only show the main experimental results, and the experimental setup and detailed analysis are shown in the Appendix.

5.1 Experiments on Zero-Shot Relation Extraction

Table 1 summarizes the experimental results of our model with the baseline model on Wiki-ZSL and FewRel, where bold denotes the best score and underline denotes the second best score. As can be seen from the table, (1) our method significantly outperforms other baselines, and combining the F1 scores under different unseen relation settings, TGCRE improves 7.73% and 4.56% on the Wiki-ZSL and FewRel datasets, respectively. (2) Although both TGCRE and ZS-BERT adopt the siamese scheme, which will lead to the relation descriptions and input instances unable to have effective information interaction. However, our method is able to effectively summarize the semantic features of different relation labels by learning the attribute knowledge of token, which makes up for the defect of insufficient relation information interaction. Therefore our approach significantly outperforms ZS-BERT. (3) RE-Matching achieves better performance through a fine-grained matching paradigm that explicitly models relations, but this baseline is semantically matched under a single vector space, which will result in the model not being able to comprehensively utilize the feature information and being susceptible to irrelevant contexts. Our approach is able to semantically match input and relation descriptions under a comprehensive

Unseen	Method	Wiki-ZSL			FewRel		
		Prec.	**Rec.**	**F1**	**Prec.**	**Rec.**	**F1**
m=5	R-BERT	39.22	43.27	41.15	42.19	48.61	45.17
	ESIM	48.58	47.74	48.16	56.27	58.44	57.33
	ZS-BERT	71.54	72.39	71.96	76.96	78.86	77.90
	RE-Matching	79.84	78.58	79.19	91.48	**90.84**	91.16
	TGCRE	**82.40**	**80.49**	**81.42**	**91.89**	90.68	**91.28**
m=10	R-BERT	26.18	29.69	27.82	25.52	33.02	28.20
	ESIM	44.12	45.46	44.78	42.89	44.17	43.52
	ZS-BERT	60.51	60.98	60.74	56.92	57.59	57.25
	RE-Matching	72.35	**72.74**	72.53	83.03	81.89	82.45
	TGCRE	**74.61**	72.07	**73.30**	**86.23**	**85.11**	**85.66**
m=15	R-BERT	17.31	18.82	18.03	16.95	19.37	18.08
	ESIM	27.31	29.62	28.42	29.15	31.59	30.32
	ZS-BERT	34.12	34.38	34.25	35.54	38.19	36.82
	RE-Matching	62.35	62.34	62.33	73.11	70.36	71.69
	TGCRE	**67.69**	**66.50**	**67.06**	**73.77**	**72.10**	**72.92**

Table 1: Experimental results on the zero-shot task.

multi-perspective view through multi-level spatial semantic matching, which mitigates the overfitting of visible relations in the training set, and thus our model still outperforms RE-Matching.

5.2 Experiments on Few-Shot Relation Extraction

Table 2 summarizes the experimental results of our model with other models on the few-shot relation extraction task. From the table, we can see that (1) our proposed TGCRE performs the best, indicating that our model is able to fully utilize the knowledge of token attributes to generate better semantic representations and effectively reduce the semantic distance between the class prototype representation and its corresponding query instance. (2) SimpleFSRE achieves better performance by introducing relation information through direct addition, again demonstrating that generating better semantic representations is often more important than complex network structures. (3) The REGRAB, which uses external knowledge, does not achieve the desired results, and one possible reason is that although external knowledge can bring additional reference information to the model, it may also introduce noise and limit the performance of the model. Instead, our approach focuses on the token itself and learns knowledge about the naturally exists attributes of the token, bringing real and reliable information about the token contribution to the model without introducing any noise. (4) GM_GEN allows a single model to focus on a single task by separating different N-way-K-shot tasks, so the model can focus on specific tasks to generate semantic representations. Similar to the idea of GM_GEN, we introduce the maximum differentiation training in the training process, which can let the model focus on specific relations to learn attribute knowledge, so our TGCRE can go further to generate semantic representations based on specific relations and achieve the most advanced performance.

6 Ablation study

For the purpose of understanding the specific contribution of each component of the TGCRE model, we designed the following ablation experiments, the experimental results are shown in Table 3.In the zero-shot task, when the token attribute vectors are removed alone, i.e., the model is not allowed to learn the attribute knowledge of the tokens to summarize the contextual semantics, the performance of TGCRE (-attribute) decreases significantly, indicating that token attributes are effective in guiding the model to focus on important tokens and generate semantic representations that contain rich contextual features. When the multi-level spatial semantic matching scheme is removed alone, the TGCRE (-mlss) performance also gets a significant decrease, which indicates that synthesizing the semantic matching scores under different vector spaces can improve the model performance, which is superior to the previous single matching mode.

Method	5-way-1-shot	5-way-5-shot	10-way-1-shot	10-way-5-shot
	validation/test	**validation/test**	**validation/test**	**validation/test**
Proto-HATT	75.01/—	87.09/90.12	62.48/– –	77.50/83.05
MLMAN	79.01/82.98	88.86/92.66	67.37/75.59	80.07/87.29
BERT-PAIR	85.66/88.32	89.48/93.22	76.84/80.63	81.76/87.02
REGRAB	87.95/90.30	92.54/94.25	80.26/84.09	86.72/89.93
HCRP	94.10/96.42	96.05/97.96	89.13/93.97	93.10/96.46
SimpleFSRE	96.21/96.63	97.07/97.93	93.38/94.94	95.11/96.39
GM_GEN	96.97/97.03	98.32/98.34	93.97/94.99	96.58/96.91
TGCRE	**97.88/98.32**	**98.71/99.02**	**95.75/95.55**	**97.79/97.84**

Table 2: Experimental results on the few-shot task, accuracy(%) as an evaluation metric.

When both of the above modules are removed at the same time, the model performance is severely impaired. From TGCRE (-attributue) and TGCRE (-both), it can be seen that the model performance is greatly impaired by removing the multi-level spatial semantic matching scheme on top of removing the token attribute vector, indicating that relying on the multi-level matching scheme alone can still allow the model to maintain excellent performance when there is no excellent semantic representation support. In the few-shot task, when we removed the maximum differentiation training objective, i.e., prohibited the model from focusing on specific relations to learn attribute knowledge, TGCRE(-dif) showed degradation in performance, which resulted in the problem of the model failing to generate good semantic representations according to a specific relation without sufficient training samples. Further, when we remove the token attribute vectors on top of TGCRE(-dif), the performance of the TGCRE(-attribute) shows a catastrophic degradation, which indicates that the model does not generate good semantic representations based on special tokens without learning knowledge of token attributes. More experimental results are detailed in Appendix G.

	Method	**m=5**	**m=10**
zero-shot	-attribute	89.99	83.59
	-mlss	91.08	83.81
	-both	88.06	83.14
	TGCRE	**91.28**	**85.66**
	Method	**5-1**	**10-1**
few-shot	-dif	94.92	91.14
	-attribute	92.11	87.89
	TGCRE	**98.32**	**95.55**

Table 3: Ablation experiments on the FewRel dataset, where zero-shot is evaluated in F1 and few-shot is evaluated in accuracy.

7 Conclusions

In this paper, we propose TGCRE, a low-shot relation extraction method based on token-generated contribution. The TGCRE summarizes instance features based on the specific contributions made by each token to generate better semantic representations that unify low-shot relation extraction. Specifically, TGCRE learns knowledge of token attributes by training approximate attribute vector, which guides the model to focus on tokens that contribute significantly to sentence expression. Moreover, in the zero-shot scenario, we propose a multi-level spatial semantic matching scheme that synthesizes the matching scores from different perspectives for label matching and greatly improves the matching accuracy. Extensive experiments have proved the effectiveness of our method, achieving state-of-the-art performance.

Limitations

The token attribute information has been shown to facilitate the model in generating better semantic representations, and although we propose two approaches for generating gradient information in the paper (Mean, Classification), this is still not the optimal choice. Exploring richer gradient generation approaches that motivate models to better utilize token attribute information is a promising direction that will be the focus of our future work.

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A Task Formulation

Few-Shot RE. In resource-poor few-sample scenarios, the purpose of few-shot relation extraction is to train the model's triplet extraction capability using only a small number of training samples when there are not a large number of labeled samples in the candidate class, usually with the number of samples specified in an N-way-K-shot setting. Specifically, there is a support set S and a query set Q in different N-way-K-shot tasks, respectively. S contains N randomly sampled relation categories $r \in \boldsymbol{R}_s$ and each class r corresponds to K labeled instances s_i used for training. Q contains m (custom hyperparameters) query instances q_i for testing. The goal of the few-shot RE task is to train the model's learning ability by supporting instances s_i so that the model can quickly adapt and deal with similar types of tasks, rather than just a single classification task. Finally, the learning capability of the model is verified using instances q_i in the query set Q, predicting to which of the categories r in R_s that q_i belongs. Formally, this can be formulated as:

$$S \xrightarrow{\text{train}} M(LB) \xleftarrow{\text{validation}} Q \tag{17}$$

where *M(LB)* represents the learning capacity learned by the model.

Zero-Shot RE. In zero-sample scenarios where no data resources are available, zero-shot RE aims to use existing well-labeled datasets to train the model's triple-extraction capability and then apply it to extract the relations of entity pairs from new unseen data. Specifically, each relation $r \in \boldsymbol{R}$ in the dataset corresponds to a relation description $d \in \boldsymbol{D}$. A model is trained to measure the distance between sentence instances I and relation descriptions D, and to predict to which type r in R that I belongs. The goal of zero-shot RE is to use relation-visible data Y_s to train the knowledge transfer capability of the model, allowing the model to use past knowledge to infer and recognize new things that have not been seen before. Ultimately, relation-invisible data Y_u is used to validate the model's knowledge transfer capability. Formally, this can be formulated as:

$$Y_s \xrightarrow{\text{train}} M(KG) \xleftarrow{\text{validation}} Y_u \tag{18}$$

where *M(KG)* represents the knowledge transfer capability learned by the model and $Y_s \cap Y_u = \emptyset$.

B Encoding

Sentence Encoding. For any given input instance $I = \{x_1, x_2, \ldots, x_n\}$, the head entity e_h^I and the tail entity e_t^I are surrounded by the special symbols "#" and "@", respectively. We use the pre-trained language model BERT as a sentence encoder with encoded context features formulated as $\tilde{I} = \{h_1^I, h_2^I, \ldots, h_n^I\}$, and then extract the head entity feature $\tilde{e_h^I}$ and tail entity feature $\tilde{e_t^I}$ from the context features based on the locations of the specially tagged annotated entities using maximum pooling.

Relation Description Encoding. For any given relation description $d = \{d_1, d_2, \ldots, d_n\}$, we use an independently fixed sentence-BERT as a relation description encoder, following the work of Zhao et al. (2023a) et al., we extract the contextual features of the relation description $\tilde{d} = \{h_1^d, h_2^d, \ldots, h_n^d\}$ and the head entity description features $\tilde{e_h^d}$ and tail entity description feature $\tilde{e_t^d}$.

C Datasets

We evaluated our method on two popular datasets in low-shot RE. The FewRel dataset is used in the few-shot RE task, and the FewRel and Wiki-ZSL datasets are used in the zero-shot RE task.

FewRel dataset consists of 70,000 sentences from 100 relations on Wikipedia, annotated by crowdfunding workers. The standard FewRel follows the setup of training/validation/testing sets corresponding to 64/16/20 relation categories, where the training and validation sets are publicly accessible, whereas the testing set is not.

Wiki-ZSL dataset contains 113 relations and 94,383 instances from Wikipedia, completed by remote supervised annotation. The dataset is divided into three subsets: training set/validation set/test set, corresponding to 98/5/10 relation categories, respectively.

D Baseline Models

In order to evaluate the effectiveness of our method, we compare TGCRE with state-of-the-art methods in the few-shot RE and zero-shot RE tasks, respectively, selecting a representative number of models from recent years.

For the few-shot RE, the models include Proto-HATT(Gao et al., 2019a), MLMAN(Ye and Ling, 2019), BERT-PAIR(Gao et al., 2019b), RE-GRAB(Qu et al., 2020), HCRP(Han et al., 2021), SimpleFSRE(Liu et al., 2022), and GM_GEN(Li and Qian, 2022). For zero-shot RE, the models include R-BERT(Wu and He, 2019), ESIM(Levy et al., 2017), ZS-BERT(Chen and Li, 2021), and RE-Matching(Zhao et al., 2023a).

E Experimental settings

Following existing methods, we use Bert-base(Devlin et al., 2019) as an encoder for the input sentences. In particular, we employ a separate fixed sentence-Bert(Reimers and Gurevych, 2019) for the relation descriptions as an encoder, with the aim of reducing the computational overhead.

In the zero-shot RE task, the learning rate is set to 2e-6, batchsize is set to 16, and 10 epochs are trained. We randomly choose $m \in \{5, 10, 15\}$ relations as visible relations in the test set and consider the rest as visible relations in the training set. In this paper, we randomly repeat the relation category selection five times and report the average results under different selections to ensure the reliability of the experimental results.

In the few-shot RE task, the learning rate is set to 1e-5, the batchsize is set to 2, and the number of training iterations and validation iterations are set to 30,000 and 1,000, respectively. Following the official evaluation setup, we use 5-way-1-shot, 5-way-5-shot, 10-way-1-shot, and 10-way-5-shot to measure the performance of the model on the validation and test sets.

AdamW(Loshchilov and Hutter, 2017) is used as an optimizer in both the above tasks. In this paper, the IDE used for the experiments is Pycharm 2021 Professional Edition. PyTorch version 1.9.1; CUDA version 11.7. model training and inference were performed on an NVIDIA A100-SMX with 40GB of GPU memory and 16GB of CPU memory.

F Case Study

F.1 Analysis of different semantic summarization approaches

In order to compare the advantages and disadvantages of each semantic summarization approach, we designed the following comparison experiments,

Method	Prec.	Rec.	F1
CLS	91.38	90.47	90.92
CLS+Avg	89.56	88.44	88.99
$E_h + E_t$	90.24	89.34	89.99
Attribute	**91.89**	**90.68**	**91.28**

Table 4: Comparison of different semantic summarization approaches.

and the results are shown in Table 4. We take the FewRel dataset as an example and use TGCRE as the base model for zero-shot relation extraction using different semantic summarization approaches. From the experimental results, it can be seen that the semantic summarization approach based on token attributes proposed in this paper achieves the best performance in all three metrics, which is superior to previous approaches based on special tokens. In particular, *CLS+Avg* achieves only 88.99 and $E_h + E_t$ up to 89.99 in terms of F1 metrics, which suggests that they do not seem to achieve the desired results in an unsupervised task that lacks supervised signals. Instead, the use of the most simple [CLS] as an embedding token for semantic summarization reached 90.92, just below our proposed approach.

F.2 Analysis of different forward-backward procedures

In order to understand the impact of our proposed two forward-backward procedures, *Mean* and *Classification*, on the performance of the model, we set up relevant experiments by randomly sampling the set of invisible relations five times with unseen=5. The experimental results are shown in Table 5. We observe the counterfactual that the *Classification* method based on supervised labeling is actually lower than the simple *Mean* method, although there is no large gap between the two methods. From the results of the five random samples, each of the two emerged victorious and defeated, possibly due to the chance of random sampling. We believe that another important reason is that the *Classification* method, despite the additional support provided by the supervised signals, only undergoes one backward pass, which makes the gradient information generated by each token more contingent, and the model suffers from more noise compared to the *Mean* method.

Method	Random	Prec.	Rec.	F1
Mean	0	94.58	94.63	94.60
Classification	0	94.88	94.57	**94.73**
Mean	1	90.37	87.74	**89.03**
Classification	1	89.63	86.29	87.93
Mean	2	83.45	83.09	83.37
Classification	2	85.42	83.46	**84.43**
Mean	3	93.55	92.89	**93.22**
Classification	3	93.35	92.89	93.12
Mean	4	96.33	96.34	**96.34**
Classification	4	96.18	96.20	96.19
Mean	average	91.66	**90.94**	**91.31**
Classification	average	**91.89**	90.68	91.28

Table 5: Comparison of different forward-backward procedures.

Unseen	Method	Wiki-ZSL	FewRel
m=5	-attribute	81.33	89.99
	-mlss	81.06	91.08
	-both	80.15	88.06
	TGCRE	81.42	91.28
m=10	-attribute	71.97	83.59
	-mlss	71.04	83.81
	-both	71.47	83.14
	TGCRE	73.30	85.66
m=15	-attribute	66.45	72.39
	-mlss	66.40	72.09
	-both	66.16	71.72
	TGCRE	67.06	72.92

Table 6: Ablation experiments on zero-shot, evaluated in terms of F1.

Method	5-1	5-5	10-1	10-5
-dif	94.92	97.05	91.14	94.80
-attribute	92.11	97.90	87.89	96.52
TGCRE	98.32	99.02	95.55	97.84

Table 7: Ablation experiments on few-shot, evaluated in terms of accuracy.

G Ablation Experiments

We show the results of the full ablation experiments. Table 6 presents the ablation experiments of the TGCRE in the zero-shot task and Table 7 presents the ablation experiments of the TGCRE in the few-shot task.