Connecting Embeddings for Knowledge Graph Entity Typing

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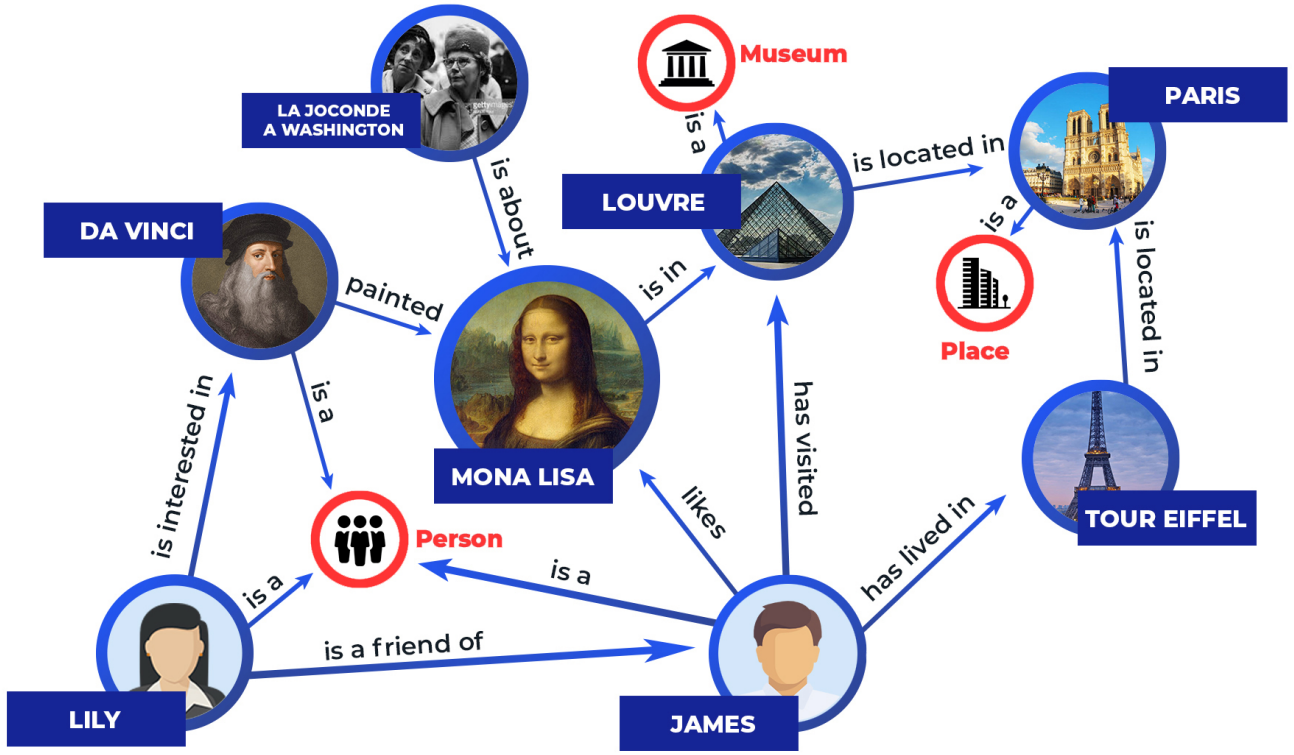
Outline

- Background
- Method
- Experiment
- Conclusion & Review

Background

Graph Entity Typing



Knowledge Graph

(e_1, r, e_2)
以实体-关系-实体三元组所构建的知识图谱

Entity Typing

(e, t)
引入实体-类型二元组对知识图谱进行补充

Background

Problem Definition

Given:

$\{(e_1, r, e_2)\}^N$

$\{e_{typed}, t\}^M$

Predict:

$\{e_{untyped}, ?\}^{M'}$

Previous Works

- Classification Methods
- Embedding-based Methods
- Hybrid Methods

Method

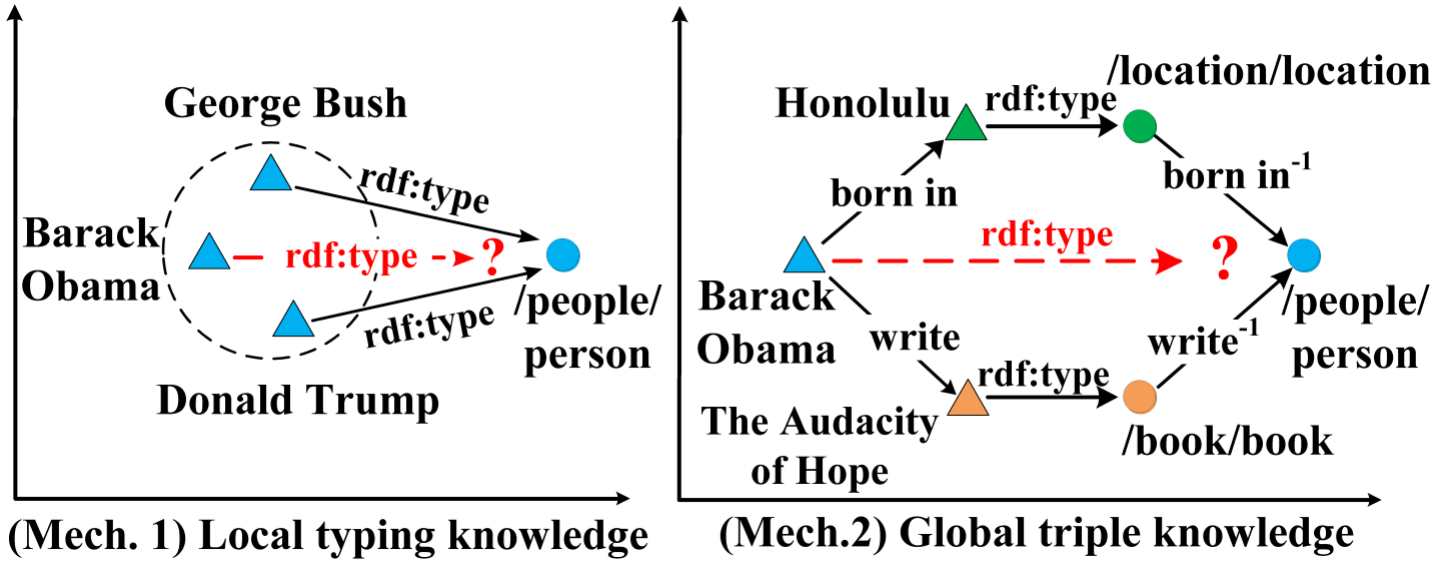
Motivation

Previous works' weakness: Ignore structure knowledge in graph

Solution

Leverage assumption knowledge to the embedding learning process.

- Missing type can be found in similar entities
- Missing type can be inferred from types of related entities



Method

Embedding Space Modeling

E2T: Mapping Entities to Types

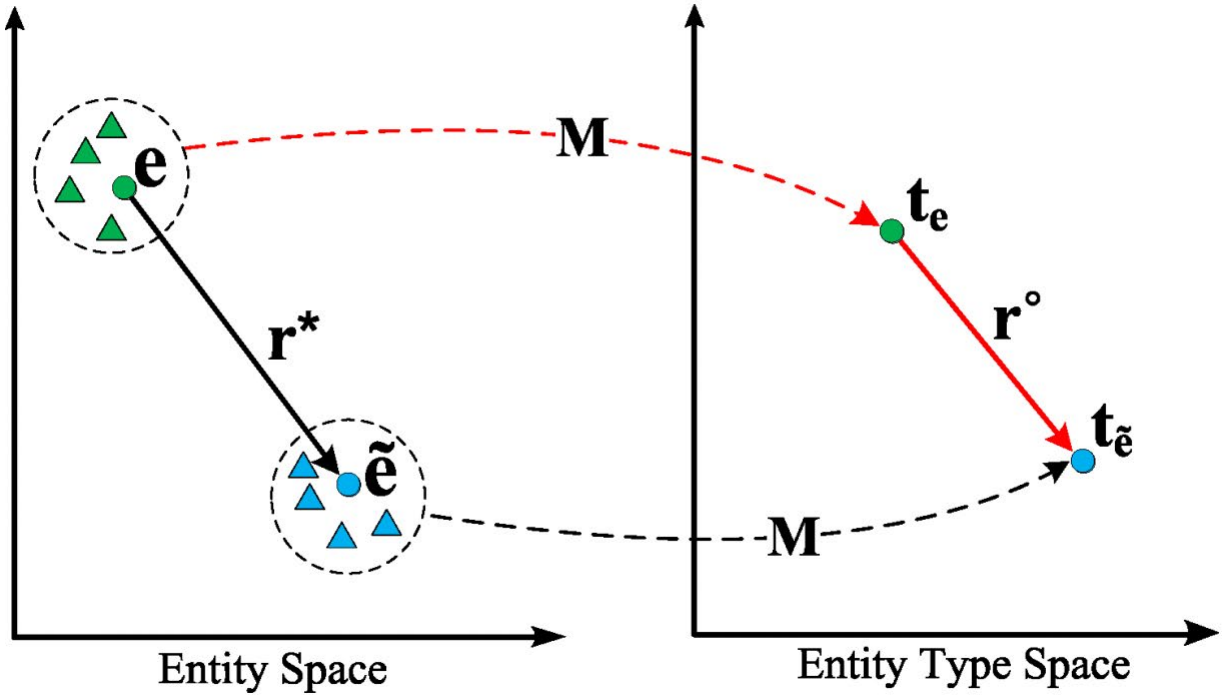
$$f_{proj}(\boldsymbol{e}) \simeq \boldsymbol{t}_e$$

$$\boldsymbol{S}_{e2t}(e,t) = \|\boldsymbol{M}\cdot\boldsymbol{e} - \boldsymbol{t}\|_2^2$$

TRT: Encoding Triples in KGs

$$(e, r^*, \tilde{e}) \xrightarrow{replace} (t_e, r^\circ, t_{\tilde{e}})$$

$$\boldsymbol{S}_{trt}(t_e, r, t_{\tilde{e}}) = \left\|\boldsymbol{t_e} + \boldsymbol{r}^\circ - \boldsymbol{t_{\tilde{e}}}\right\|_2^2$$



Method

Entity Type Prediction

$$\boldsymbol{S}_{e2t+trt}(e,t_e) = \lambda \boldsymbol{S}_{e2t}(e,t) + (1-\lambda)\left\{\frac{1}{|P|}\sum_{t_{\tilde{e}}\in P}\boldsymbol{S}_{trt}(t_e,r,t_{\tilde{e}}) + \frac{1}{|Q|}\sum_{t_{\bar{e}}\in Q}\boldsymbol{S}_{trt}(t_{\bar{e}},r,t_e)\right\}$$

$$\hat{t}_e = \arg\min_{t_e\in\mathcal{T}} \boldsymbol{S}_{e2t+trt}(e,t_e)$$

Optimization

$$\mathbf{J}_1 = \sum_{\mathcal{D}}\sum_{\mathcal{D}'}[\gamma_1 + \mathbf{S}(e,r,\tilde{e}) - \mathbf{S}(e',r,\tilde{e}')]_+ ,$$

$$\mathbf{J}_2 = \sum_{\mathcal{H}}\sum_{\mathcal{H}'}[\gamma_2 + \mathbf{S}_{e2t}(e,t_e) - \mathbf{S}_{e2t}(e',t'_e)]_+ ,$$

$$\mathbf{J}_3 = \sum_{\mathcal{Z}}\sum_{\mathcal{Z}'}[\gamma_3 + \mathbf{S}_{trt}(t_e,r,t_{\tilde{e}}) - \mathbf{S}_{trt}(t'_e,r,t'_{\tilde{e}})]_+$$

$$\begin{aligned}
\mathcal{D}' :=& \{(e',r,\tilde{e})|(e,r,\tilde{e})\in\mathcal{D}, e'\in\mathcal{E}, e'\neq e\} \\
&\cup\{(e,r,\tilde{e}')|(e,r,\tilde{e})\in\mathcal{D}, \tilde{e}'\in\mathcal{E}, \tilde{e}'\neq\tilde{e}\} , \\
\mathcal{H}' :=& \{(e',t_e)|(e,t_e)\in\mathcal{H}, e'\in\mathcal{E}, e'\neq e\} \\
&\cup\{(e,t'_e)|(e,t_e)\in\mathcal{H}, t'_e\in\mathcal{T}, t'_e\neq t_e\} , \\
\mathcal{Z}' :=& \{(t'_e,r,t_{\tilde{e}})|(t_e,r,t_{\tilde{e}})\in\mathcal{Z}, t'_e\in\mathcal{T}, t'_e\neq t_e\} \\
&\cup\{(t_e,r,t'_{\tilde{e}})|(t_e,r,t_{\tilde{e}})\in\mathcal{Z}, t'_{\tilde{e}}\in\mathcal{T}, t'_{\tilde{e}}\neq t_{\tilde{e}}\}
\end{aligned}$$

Experiments

Dataset

- FB15k-FB15kET
- YAGO43k-YAGO43kET

Table 2: Statistics of $\mathcal{D}, \mathcal{H}, \mathcal{Z}$.

Dataset	#Ent	#Rel	#Train	#Valid	#Test
FB15k	14,951	1,345	483,142	50,000	59,071
YAGO43k	42,335	37	331,687	29,599	29,593

Dataset	#Ent	#Type	#Train	#Valid	#Test
FB15kET	14,951	3,851	136,618	15,749	15,780
YAGO43kET	41,723	45,182	375,853	42,739	42,750

Dataset	#Type	#Rel	#Train	Valid	Test
FB15kTRT(full)	3,851	1,345	2,015,338	–	–
FB15kTRT(disc.)	2,060	614	231,315	–	–
YAGO43kTRT(full)	45,128	37	1,727,708	–	–
YAGO43kTRT(disc.)	17,910	32	189,781	–	–

$\mathcal{D}$ (left entity, relationship, right entity)

$\mathcal{H}$ (entity, entity type)

$\mathcal{Z}$ (head type, relationship, tail type)

Experiments

Task and Evaluation

Entity Type Prediction

- Mean Reciprocal Rank

$$MRR = \frac{1}{|C|}\sum_{i=1}^{|C|}\frac{1}{rank_i},$$

- Proportion of Correct Entities Ranked

$HITS@1/3/10$

Entity Type Classification

Classified to be positive if

$$\mathbf{S}_{e2t+trt}(e, t_e) \leq \eta$$

- Precision/Recall
- Accuracy

Experiments

Analysis

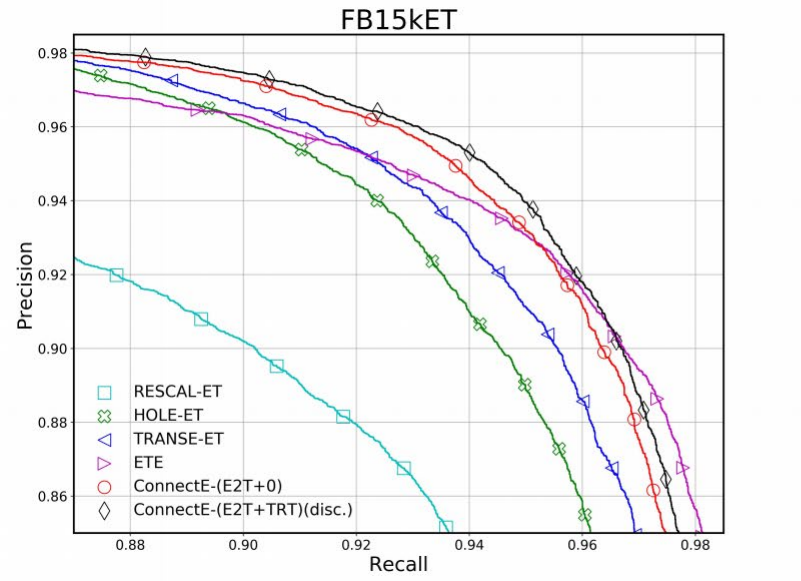
Entity Type Prediction

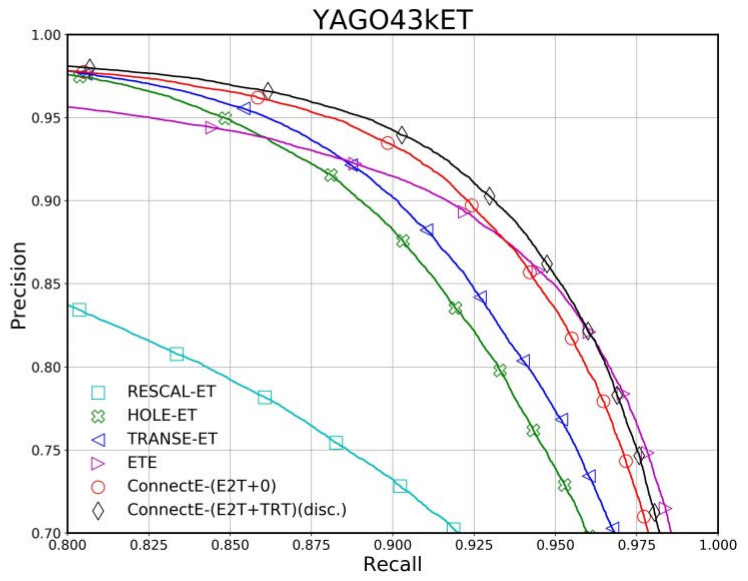
DATASET	FB15kET				YAGO43kET			
METRICS	**MRR**	**HITS@1**	**HITS@3**	**HITS@10**	**MRR**	**HITS@1**	**HITS@3**	**HITS@10**
RESCAL (Nickel et al., 2011)	0.19	9.71	19.58	37.58	0.08	4.24	8.31	15.31
RES.-ET (Moon et al., 2017)	0.24	12.17	27.92	50.72	0.09	4.32	9.62	19.40
HOLE (Nickel et al., 2016)	0.22	13.29	23.35	38.16	0.16	9.02	17.28	29.25
HOLE-ET (Moon et al., 2017)	0.42	29.40	48.04	66.73	0.18	10.28	20.13	34.90
TransE (Bordes et al., 2013)	0.45	31.51	51.45	73.93	0.21	12.63	23.24	38.93
TransE-ET (Moon et al., 2017)	0.46	33.56	52.96	71.16	0.18	9.19	19.41	35.58
ETE (Moon et al., 2017)	0.50	38.51	55.33	71.93	0.23	13.73	26.28	42.18
ConnectE-(E2T+0)	0.57 +- .00	45.54 +- .28	62.31 +- .29	78.12 +- .12	0.24 +- .01	13.54 +- .12	26.20 +- .18	44.51 +- .09
ConnectE-(E2T+TRT)(disc.)	0.59 +- .01	48.54 +- .71	63.66 +- .39	78.27 +- .16	0.27 +- .01	15.1 +- .15	29.14 +- .13	47.08 +- .09
ConnectE-(E2T+TRT)(full)	**0.59 +- .00**	**49.55 +- .62**	**64.32 +- .37**	**79.92 +- .14**	**0.28 +- .01**	**16.01 +- .12**	**30.85 +- .13**	**47.92 +- .07**

Experiments

Analysis

Entity Type Classification





Dataset	FB15kET	YAGO43kET
RESCAL-ET	90.02%	82.28%
HOLE-ET	93.23%	90.14%
TransE-ET	93.88%	90.76%
ETE	94.01%	90.82%
ConnectE (E2T+0)	94.45%	91.78%
ConnectE (E2T+TRT)(disc.)	**94.49%**	**92.33%**

Experiments

Case Study

	Type prediction: HIT@1		Rel	Tail type	
1	type=? /people/person		/location/location/ people_born_here	/location/location	
	head entity	Peter Berg		New York	tail entity
		Gus Van Sant		Louisville	
2	type=? /americancomedy/movie		/film/film/ directed_by	/film/director	
	head entity	Very Bad Things		Peter Berg	tail entity
		Rush Hour		Brett Ratner	
3	type=? /medicine/disease		people/cause_of _death/people	/people/person	
	head entity	Myocardial infarction		Dick Clark	tail entity
		Pancreatic cancer		John Hurt	

Conclusion & Review

Conclusion

- This paper propose two hypotheses
- Based on these, the author build a embedding-based framework
- The framework is utilized to infer missing entity type instances

Review

- The baseline models compared may be out of date
- The proposed method may not be suitable for fine-grained typing

Thanks