Learning Entity and Relation Embeddings for Knowledge Graph Completion

AAAI’15

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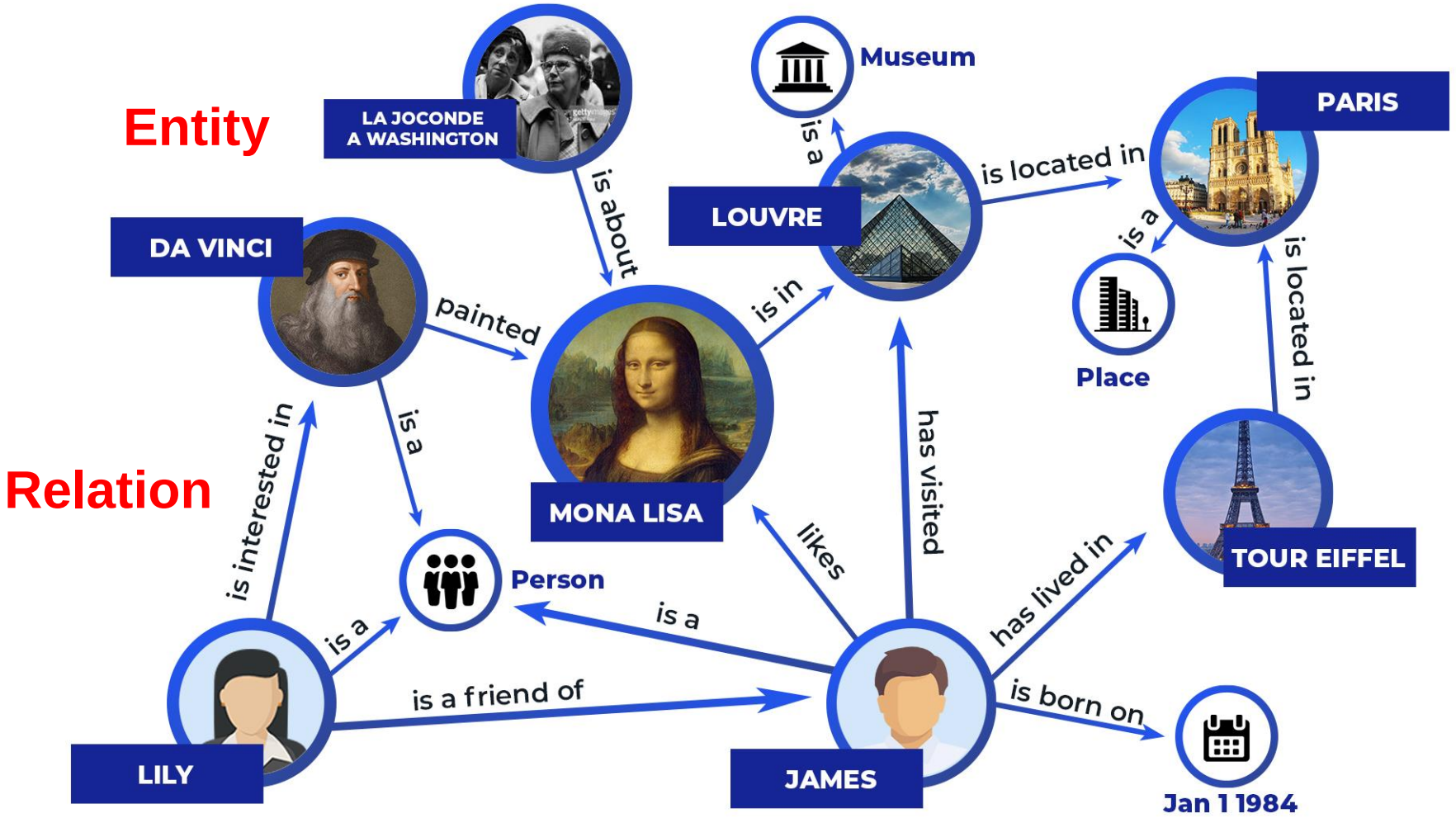
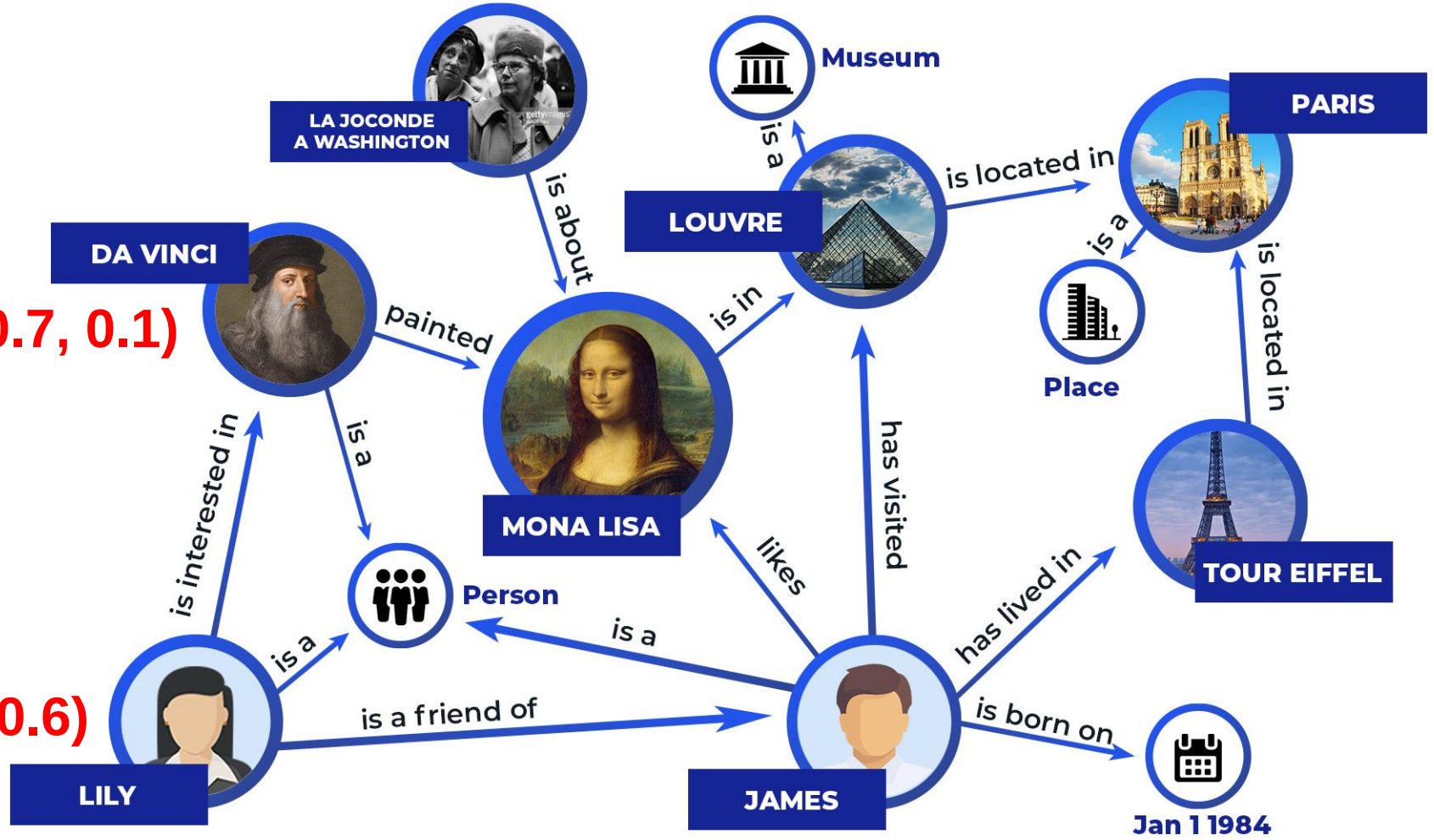
Knowledge Graph (KG)



https://yashuseth.blog/2019/10/08/introduction-question-answering-knowledge-graphs-kgqa/

Embedding



(0.3, 0.1, 0.7, 0.1)

(0.9, 0.4, 0.4, 0.6)

https://yashuseth.blog/2019/10/08/introduction-question-answering-knowledge-graphs-kgqa/

Related Work - TransE

As mentioned in Section "Introduction", TransE (Bordes et al. 2013) wants $\mathbf{h}+\mathbf{r} \approx \mathbf{t}$ when (h, r, t) holds. This indicates that $(\mathbf{t})$ should be the nearest neighbor of $(\mathbf{h} + \mathbf{r})$. Hence, TransE assumes the score function

$$f_r(h, t) = \|\mathbf{h} + \mathbf{r} - \mathbf{t}\|_2^2 \tag{1}$$

is low if (h, r, t) holds, and high otherwise.

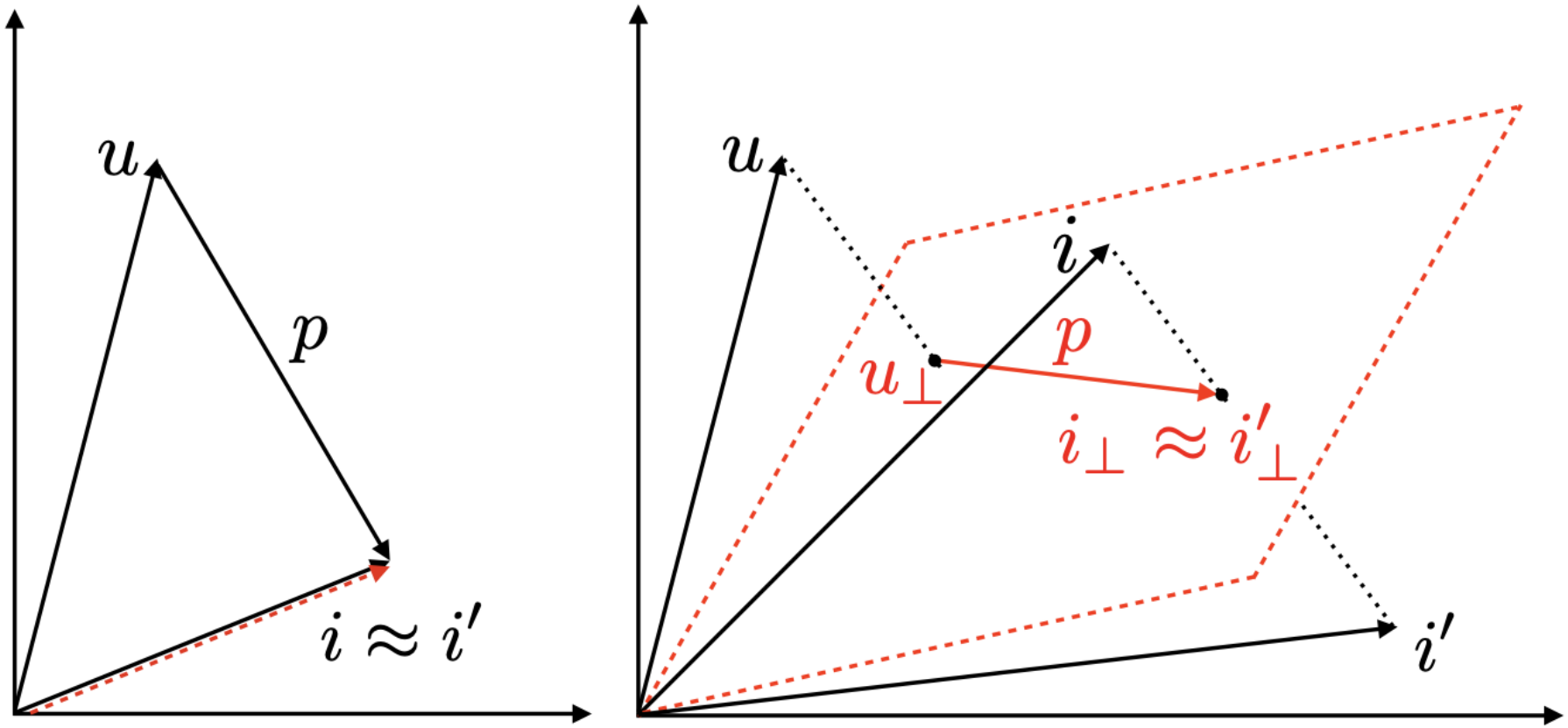
Related Work - TransH

TransH models the relation as a vector $\mathbf{r}$ on a hyperplane with $\mathbf{w}_r$ as the normal vector. For a triple (h, r, t), the entity embeddings $\mathbf{h}$ and $\mathbf{t}$ are first projected to the hyperplane of $\mathbf{w}_r$, denoted as $\mathbf{h}_\perp$ and $\mathbf{t}_\perp$. Then the score function is defined as

$$f_r(h, t) = \|\mathbf{h}_\perp + \mathbf{r} - \mathbf{t}_\perp\|_2^2. \quad (2)$$

If we restrict $\|\mathbf{w}_r\|_2 = 1$, we will have $\mathbf{h}_\perp = \mathbf{h} - \mathbf{w}_r^\top \mathbf{h}\mathbf{w}_r$ and $\mathbf{t}_\perp = \mathbf{t} - \mathbf{w}_r^\top \mathbf{t}\mathbf{w}_r$. By projecting entity embeddings into relation hyperplanes, it allows entities playing different roles in different relations.

TransE and TransH



(a) TransE (b) TransH

TransR

In TransR, for each triple (h, r, t), entities embeddings are set as $\mathbf{h}, \mathbf{t} \in \mathbb{R}^k$ and relation embedding is set as $\mathbf{r} \in \mathbb{R}^d$. Note that, the dimensions of entity embeddings and relation embeddings are not necessarily identical, i.e., $k \neq d$.

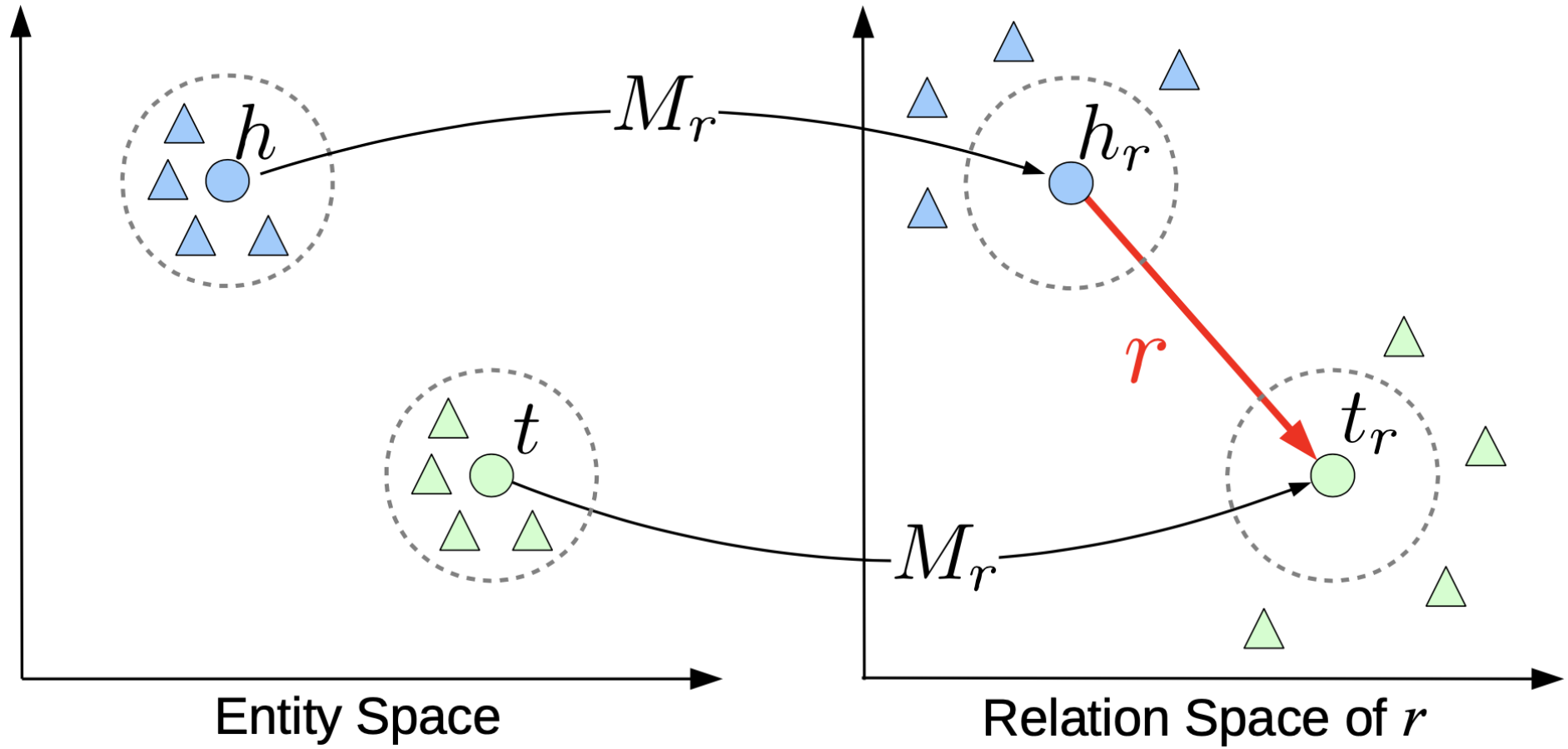
For each relation r, we set a projection matrix $\mathbf{M}_r \in \mathbb{R}^{k \times d}$, which may projects entities from entity space to relation space. With the mapping matrix, we define the projected vectors of entities as

$$\mathbf{h}_r = \mathbf{h}\mathbf{M}_r, \quad \mathbf{t}_r = \mathbf{t}\mathbf{M}_r. \tag{7}$$

The score function is correspondingly defined as

$$f_r(h, t) = \|\mathbf{h}_r + \mathbf{r} - \mathbf{t}_r\|_2^2. \tag{8}$$

TransR



Datasets

Dataset	#Rel	#Ent	#Train	#Valid	# Test
WN18	18	40,943	141,442	5,000	5,000
FB15K	1,345	14,951	483,142	50,000	59,071
WN11	11	38,696	112,581	2,609	10,544
FB13	13	75,043	316,232	5,908	23,733
FB40K	1,336	39528	370,648	67,946	96,678

Experiments

❑ Link Prediction

Data Sets	WN18				FB15K			
Metric	Mean Rank		Hits@10 (%)		Mean Rank		Hits@10 (%)	
	Raw	Filter	Raw	Filter	Raw	Filter	Raw	Filter
Unstructured (Bordes et al. 2012)	315	304	35.3	38.2	1,074	979	4.5	6.3
RESCAL (Nickel, Tresp, and Kriegel 2011)	1,180	1,163	37.2	52.8	828	683	28.4	44.1
SE (Bordes et al. 2011)	1,011	985	68.5	80.5	273	162	28.8	39.8
SME (linear) (Bordes et al. 2012)	545	533	65.1	74.1	274	154	30.7	40.8
SME (bilinear) (Bordes et al. 2012)	526	509	54.7	61.3	284	158	31.3	41.3
LFM (Jenatton et al. 2012)	469	456	71.4	81.6	283	164	26.0	33.1
TransE (Bordes et al. 2013)	263	251	75.4	89.2	243	125	34.9	47.1
TransH (unif) (Wang et al. 2014)	318	303	75.4	86.7	211	84	42.5	58.5
TransH (bern) (Wang et al. 2014)	401	388	73.0	82.3	212	87	45.7	64.4
TransR (unif)	232	219	78.3	91.7	226	78	43.8	65.5
TransR (bern)	238	225	**79.8**	92.0	**198**	77	48.2	68.7
CTransR (unif)	243	230	78.9	**92.3**	233	82	44	66.3
CTransR (bern)	**231**	**218**	79.4	**92.3**	199	**75**	**48.4**	**70.2**