



Learning Entity and Relation Embeddings for Knowledge Graph Completion

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Related Models: TransE

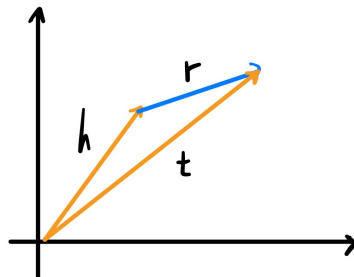
지식 그래프 구조



Head entity : 관계의 시작 노드

Tail entity : 관계의 끝 노드

TransE



$$\mathbf{h} + \mathbf{r} \approx \mathbf{t}$$

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

TransE의 scoring function

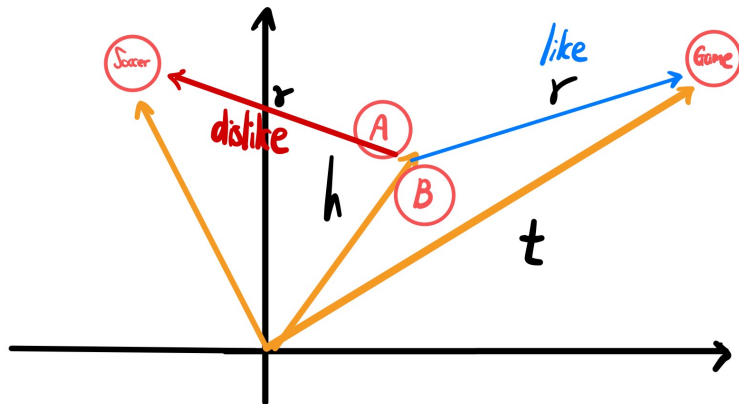
Related Models: TransE

TransE의 문제점

(A, like, Game)

(B, like, Game)

(A, dislike, Soccer)

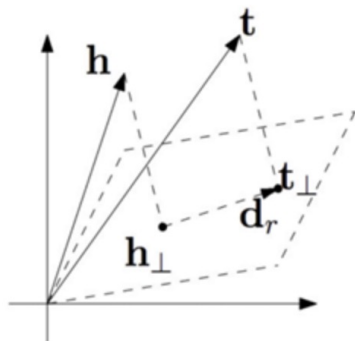


A와 B는 “like” relation에 대해 비슷한 위치에 임베딩
하지만 A는 B와 달리 Soccer에 대한 “dislike” relation이 존재

Entity가 가질 수 있는 여러 가지 relation 고려 x

Related Models: TransH

TransH



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

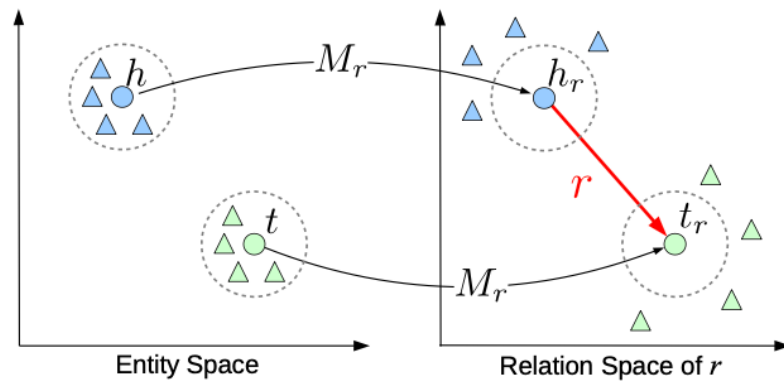
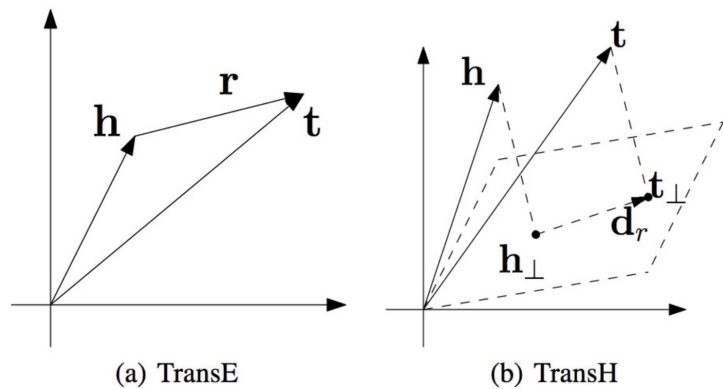
TransH의 scoring function

$$\mathbf{h}_\perp = \mathbf{h} - \mathbf{w}_r^\top \mathbf{h} \mathbf{w}_r$$

$$\mathbf{t}_\perp = \mathbf{t} - \mathbf{w}_r^\top \mathbf{t} \mathbf{w}_r \quad \text{in } \|\mathbf{w}_r\|_2 = 1$$

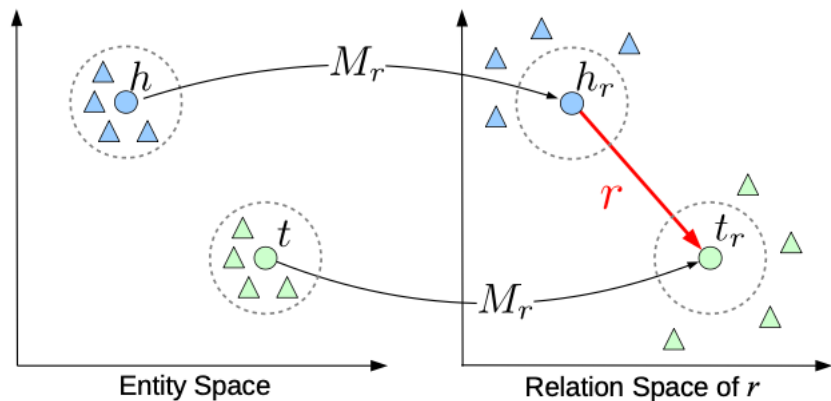
각 relation은 고유한 hyperplane \mathbf{w}_r 를 가짐

Related Models: TransE, TransH



두 방식 모두 entity와 relation이 동일한 space에 존재

TransR



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

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

$$\mathbf{h}, \mathbf{t} \in \mathbb{R}^k \quad \mathbf{r} \in \mathbb{R}^d$$

Projection matrix $\mathbf{M}_r \in \mathbb{R}^{k \times d}$

Entity space에서 모여있던 entity들이
특정 relation space에선 다르게 위치 됨

CTransR

relation: location - location - contains

국가-도시

↓ r_{c1}

국가-대학

↓ r_{c2}

대학-국가

↓ r_{c3}

$$\mathbf{h}_{r,c} = \mathbf{h}\mathbf{M}_r \quad \mathbf{t}_{r,c} = \mathbf{t}\mathbf{M}_r$$

$$f_r(h, t) = \|\mathbf{h}_{r,c} + \mathbf{r}_c - \mathbf{t}_{r,c}\|_2^2 + \alpha \|\mathbf{r}_c - \mathbf{r}\|_2^2$$

클러스터에 대해 분리된 r_c 와
각 relation에 대한 matrix \mathbf{M}_r 학습

Experiment 분석: Link prediction

삼중항 (h, r, t)에서 누락된 h 또는 t를 예측하는 실험

Mean Rank: 정답 entity의 평균 rank

Hist@10: 상위 10개 rank내에 정답 entity가 포함되는 비율

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

Raw: 실제 데이터셋

Filter: 실제 그래프에서 존재하지 않는 triple 제거

Experiment 분석: Link prediction

Tasks	Predicting Head(Hits@10)				Predicting Tail(Hits@10)			
Relation Category	1-to-1	1-to-N	N-to-1	N-to-N	1-to-1	1-to-N	N-to-1	N-to-N
Unstructured (Bordes et al. 2012)	34.5	2.5	6.1	6.6	34.3	4.2	1.9	6.6
SE (Bordes et al. 2011)	35.6	62.6	17.2	37.5	34.9	14.6	68.3	41.3
SME (linear) (Bordes et al. 2012)	35.1	53.7	19.0	40.3	32.7	14.9	61.6	43.3
SME (bilinear) (Bordes et al. 2012)	30.9	69.6	19.9	38.6	28.2	13.1	76.0	41.8
TransE (Bordes et al. 2013)	43.7	65.7	18.2	47.2	43.7	19.7	66.7	50.0
TransH (unif) (Wang et al. 2014)	66.7	81.7	30.2	57.4	63.7	30.1	83.2	60.8
TransH (bern) (Wang et al. 2014)	66.8	87.6	28.7	64.5	65.5	39.8	83.3	67.2
TransR (unif)	76.9	77.9	38.1	66.9	76.2	38.4	76.2	69.1
TransR (bern)	78.8	89.2	34.1	69.2	79.2	37.4	90.4	72.1
CTransR (unif)	78.6	77.8	36.4	68.0	77.4	37.8	78.0	70.3
CTransR (bern)	81.5	89.0	34.7	71.2	80.8	38.6	90.1	73.8

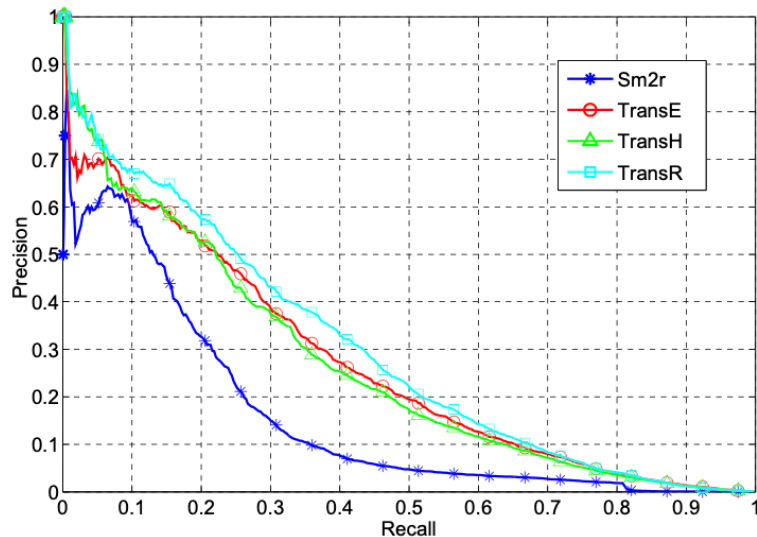
Experiment 분석: Triple classification

주어진 삼중항 (h, r, t)가 올바른지 여부를 판단하는 이진 분류 문제

Data Sets	WN11	FB13	FB15K
SE	53.0	75.2	-
SME (bilinear)	70.0	63.7	-
SLM	69.9	85.3	-
LFM	73.8	84.3	-
NTN	70.4	87.1	68.5
TransE (unif)	75.9	70.9	79.6
TransE (bern)	75.9	81.5	79.2
TransH (unif)	77.7	76.5	79.0
TransH (bern)	78.8	83.3	80.2
TransR (unif)	85.5	74.7	81.7
TransR (bern)	85.9	82.5	83.9
CTransR (bern)	85.7	-	84.5

Experiment 분석: Relation extraction

대규모 평문 텍스트에서 관계 사실을 추출하는 실험



Precision-recall 곡선을 사용하여 평가
재현율 0.05 이후부터 TransR이 높은 성능을 보임

Conclusion

Entity의 여러 relation을 표현하지 못하거나 (TransE),

Entity와 relation을 같은 공간에 임베딩(TransE, TransH) 하는 기존 방식의 문제점 존재

Entity와 relation의 공간을 분리한 TransR과 cluster-based의 CTransR 제시

Link prediction, Triple classification, Relation extraction from text에서 모두 우수한 성능을 나타냄