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TransERR: Translation-based Knowledge Graph Embedding via Efficient Relation Rotation

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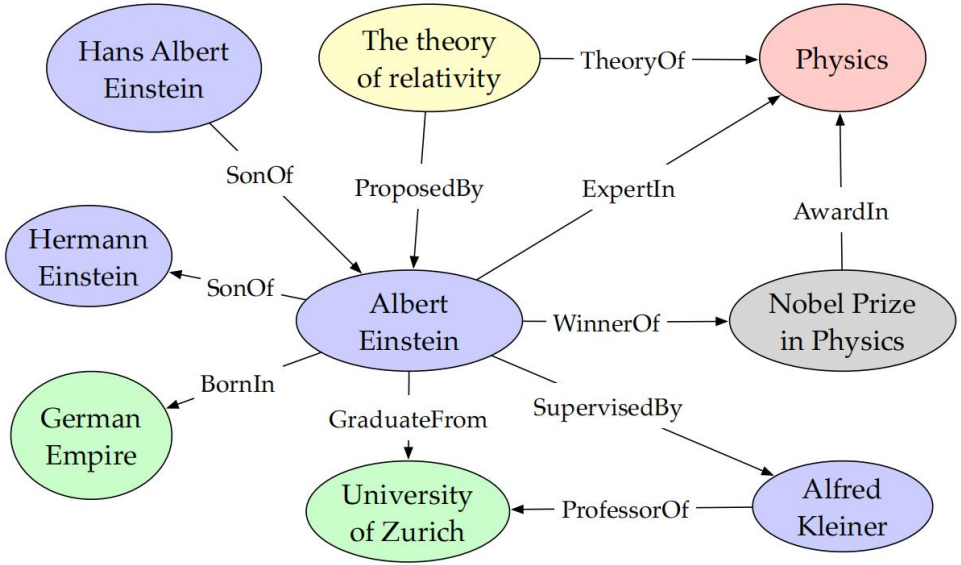
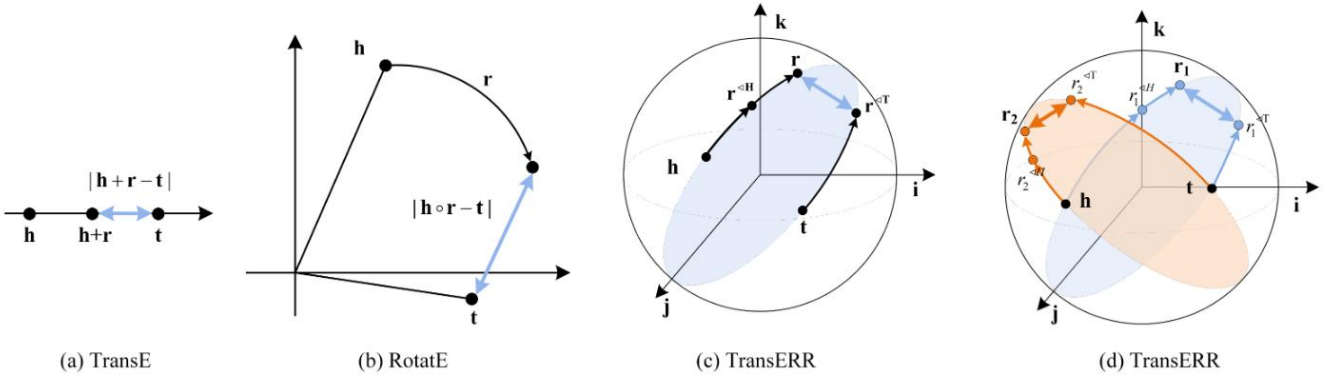
Knowledge Graph

Knowledge graphs (KGs) are multi-relation graphs of fact triples and represented as (h, r, t).



- A Survey on Knowledge Graphs: Representation, Acquisition and Applications TNNLS 2021

TransERR



(a) TransE (b) RotatE (c) TransERR (d) TransERR

Figure 1: Illustration of TransE, RotatE and TransERR. TransE, RotatE and TransERR encode knowledge graphs in the real-valued space, complex-valued space and hypercomplex-valued space, respectively. $\circ$ denotes Hadamard product. The distance function of TransERR is $\| \mathbf{h} \otimes \mathbf{r}^{\triangleleft \mathbf{H}} + \mathbf{r} - \mathbf{t} \otimes \mathbf{r}^{\triangleleft \mathbf{T}} \|$.

$$d_r(\mathbf{h}, \mathbf{t}) = \| \mathbf{h} \otimes \mathbf{r}^{\triangleleft \mathbf{H}} + \mathbf{r} - \mathbf{t} \otimes \mathbf{r}^{\triangleleft \mathbf{T}} \| .$$

Main Results

	ogbl-wikikg2				ogbl-biokg			
	#Dim	#Params	Test MRR	Valid MRR	#Dim	#Params	Test MRR	Valid MRR
TransE	500	1,250M	0.4256	0.4272	2,000	187M	0.7452	0.7456
DistMult	500	1,250M	0.3729	0.3506	2,000	187M	0.8043	0.8055
ComplEx	250	1,250M	0.4027	0.3759	1,000	187M	0.8095	0.8105
RotatE	250	1,250M	0.4332	0.4353	1,000	187M	0.7989	0.7997
Rot_Pro	200	1,000M	0.5602	0.5740	-	-	-	-
PairRE	200	500M	0.5208	0.5423	2,000	187M	0.8164	0.8172
TripleRE	200	500M	0.5794	0.6045	2,000	187M	0.8191	0.8192
TranSHER	200	500M	0.5536	0.5662	2,000	187M	0.8233	0.8244
TransERR	100	**250M**	0.6100	0.6246	1,000	**93M**	0.8153	0.8156
TransERR	200	500M	**0.6359**	**0.6518**	2,000	187M	**0.8243**	**0.8249**

Table 2: Results on ogbl-wikikg2 and ogbl-biokg. Results are taken from the official leaderboard (Hu et al., 2020). The dashes mean that the results are not reported in the responding literature.

Main Results

	WN18RR					FB15K-237				
	MR	MRR	Hits@10	Hits@3	Hits@1	MR	MRR	Hits@10	Hits@3	Hits@1
TransE ♡	3384	0.266	0.501	-	-	357	0.294	0.465	-	-
DistMult ♡	5110	0.43	0.49	0.44	0.39	254	0.241	0.419	0.263	0.155
ComplEx ♡	5261	0.44	0.51	0.46	0.41	339	0.247	0.428	0.275	0.158
TuckER	-	0.470	0.526	0.482	0.443	-	0.358	0.544	0.394	**0.266**
RotatE ♡	3340	0.476	0.571	0.492	0.428	177	0.338	0.533	0.375	0.241
Rotat3D	3328	0.489	0.579	0.505	0.442	165	0.347	0.543	0.385	0.250
QuatE	3472	0.481	0.564	0.500	0.436	176	0.311	0.495	0.342	0.221
Rot_Pro	2815	0.457	0.557	0.482	0.397	201	0.344	0.540	0.383	0.246
PairRE	-	-	-	-	-	160	0.351	0.544	0.387	0.256
TripleRE	-	-	-	-	-	142	0.351	0.544	0.387	0.256
TranSHER	-	-	-	-	-	-	**0.360**	0.551	**0.397**	0.264
TransERR	**1167**	**0.501**	**0.605**	**0.520**	**0.450**	**125**	**0.360**	**0.555**	0.396	0.264

Table 3: Results on WN18RR and FB15K-237. Results of ♡ are taken from Sun et al. (2019). The best results are in bold. The dashes mean that the results are not reported in the responding literature.

	WN18					FB15K				
	MR	MRR	Hits@10	Hits@3	Hits@1	MR	MRR	Hits@10	Hits@3	Hits@1
TransE ♡	-	0.495	0.943	0.888	0.111	-	0.463	0.749	0.578	0.297
DistMult ♡	665	0.797	0.946	-	-	42	0.798	0.893	-	-
ComplEx ♡	-	0.941	0.947	0.945	0.936	-	0.692	0.840	0.759	0.599
TuckER	-	**0.953**	0.958	0.955	**0.949**	-	0.795	0.892	0.833	0.741
RotatE ♡	309	0.949	0.959	0.952	0.944	40	0.797	0.884	0.830	0.746
Rotat3D	214	0.951	0.961	0.953	0.945	39	0.789	0.887	0.835	0.728
QuatE	338	0.949	0.960	0.954	0.941	41	0.770	0.878	0.821	0.700
PairRE	401	0.941	0.956	0.950	0.940	37	0.811	**0.896**	0.845	0.765
TripleRE	-	-	-	-	-	**35**	0.747	0.877	0.813	0.662
TransERR	**82**	**0.953**	**0.965**	**0.957**	0.945	41	**0.815**	**0.896**	**0.848**	**0.767**

	YAGO3-10					DB100K				
	MR	MRR	Hits@10	Hits@3	Hits@1	MR	MRR	Hits@10	Hits@3	Hits@1
TransE	-	-	-	-	-	-	0.111	0.270	0.164	0.016
DistMult	5926	0.34	0.54	0.38	0.24	-	0.233	0.448	0.301	0.115
ComplEx	6351	0.36	0.55	0.40	0.26	-	0.242	0.440	0.312	0.126
ConvE	1671	0.44	0.62	0.49	0.35	-	-	-	-	-
Rot_Pro	1797	0.542	0.699	0.596	0.443	867	0.359	0.599	0.471	0.306
PairRE	-	-	-	-	-	-	0.412	0.600	0.472	0.309
TranSHER	-	-	-	-	-	-	0.431	0.589	0.476	0.345
TransERR	**476**	**0.546**	**0.706**	**0.601**	**0.456**	**571**	**0.465**	**0.622**	**0.510**	**0.380**

Table 5: Results on YAGO3-10 and DB100K. Results are taken from the corresponding original papers. The best results are in bold. The dashes mean that the results are not reported in the responding literature.

	Sports					Location				
	MR	MRR	Hits@10	Hits@3	Hits@1	MR	MRR	Hits@10	Hits@3	Hits@1
SimplE ♠	-	0.230	0.324	0.234	0.184	-	0.190	0.315	0.210	0.130
SimplE$^+$ ♠	-	0.404	0.508	0.440	0.394	-	0.440	0.450	0.440	0.430
RotatE ♢	191	0.420	0.535	0.503	0.420	73	0.486	0.550	0.480	0.455
PairRE ♡	-	0.468	-	-	0.416	-	-	-	-	-
TranSHER ♢	151	0.479	0.537	0.509	0.433	71	0.475	0.575	0.470	0.435
TransERR	**95**	**0.499**	**0.570**	**0.526**	**0.447**	**30**	**0.563**	**0.645**	**0.565**	**0.520**

Table 6: Results on Sports and Location. Results of ♠ and ♡ are taken from Fatemi et al. (2019) and Chao et al. (2021), respectively. ♢ are obtained from our experiments. The best results are in bold. The dashes mean that the results are not reported in the responding literature.

1-1,1-N,N-N

Relation Type	1-to-1	1-to-N	N-to-1	N-to-N	1-to-1	1-to-N	N-to-1	N-to-N
	Head prediction (MRR)				Tail prediction (MRR)			
TransE	0.494	0.456	0.083	0.252	0.481	0.073	0.751	0.365
DistMult	0.213	0.440	0.071	0.229	0.212	0.053	0.727	0.345
ComplEx	0.356	0.465	0.091	0.247	0.373	0.062	0.741	0.356
RotatE	0.502	0.465	0.092	0.259	0.486	0.078	0.756	0.375
PairRE	0.493	0.482	0.116	0.271	0.492	0.071	0.775	0.386
TripleRE	0.499	0.485	0.116	0.283	0.493	0.077	0.776	0.388
TranSHER	0.501	0.487	**0.119**	**0.285**	0.494	0.079	0.779	0.389
TransERR	**0.515**	**0.495**	0.117	0.284	**0.515**	**0.080**	**0.785**	**0.393**
	Head prediction (Hits@10)				Tail prediction (Hits@10)			
TransE	0.494	0.456	0.083	0.252	0.481	0.073	0.751	0.365
DistMult	0.452	0.640	0.139	0.421	0.449	0.115	0.839	0.559
ComplEx	0.452	0.643	0.142	0.423	0.445	0.114	0.845	0.563
RotatE	0.601	0.672	0.175	0.468	0.586	0.143	0.880	0.615
PairRE	0.603	0.670	0.213	0.482	0.599	0.149	0.892	0.620
TripleRE	0.611	0.671	0.215	0.486	0.601	0.154	0.890	0.620
TranSHER	0.615	0.674	0.211	0.488	0.604	**0.162**	0.891	0.624
TransERR	**0.645**	**0.696**	**0.226**	**0.495**	**0.619**	0.157	**0.897**	**0.632**

Table 7: Results on FB15k-237 by relation category. Best results are in bold. Head prediction: predicting h given $(?, r, t)$. Tail prediction: predicting t given $(h, r, ?)$.

Summary

- This paper proposes a simple yet effective distancebased KGE model (TransERR), which rotates entities with two normalized quaternion vectors in the hypercomplex-valued space. TransERR possesses a higher degree of translation freedom for graph embeddings.

- We provide formal mathematical proofs to demonstrate that TransERR can encode the key relation patterns. Moreover, the results show that TransERR can effectively model complex relation patterns, including 1-1, 1-N, N1 and N-N.

- The experiments also suggest that TransERR can maximize interaction information between entities in the hypercomplex-valued space. The experimental results fully illustrate the effectiveness and generalizability of our model.

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Thank you !!!

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