TeDS: Joint Learning of Diachronic and Synchronic Perspectives in Quaternion Space for Temporal Knowledge Graph Completion

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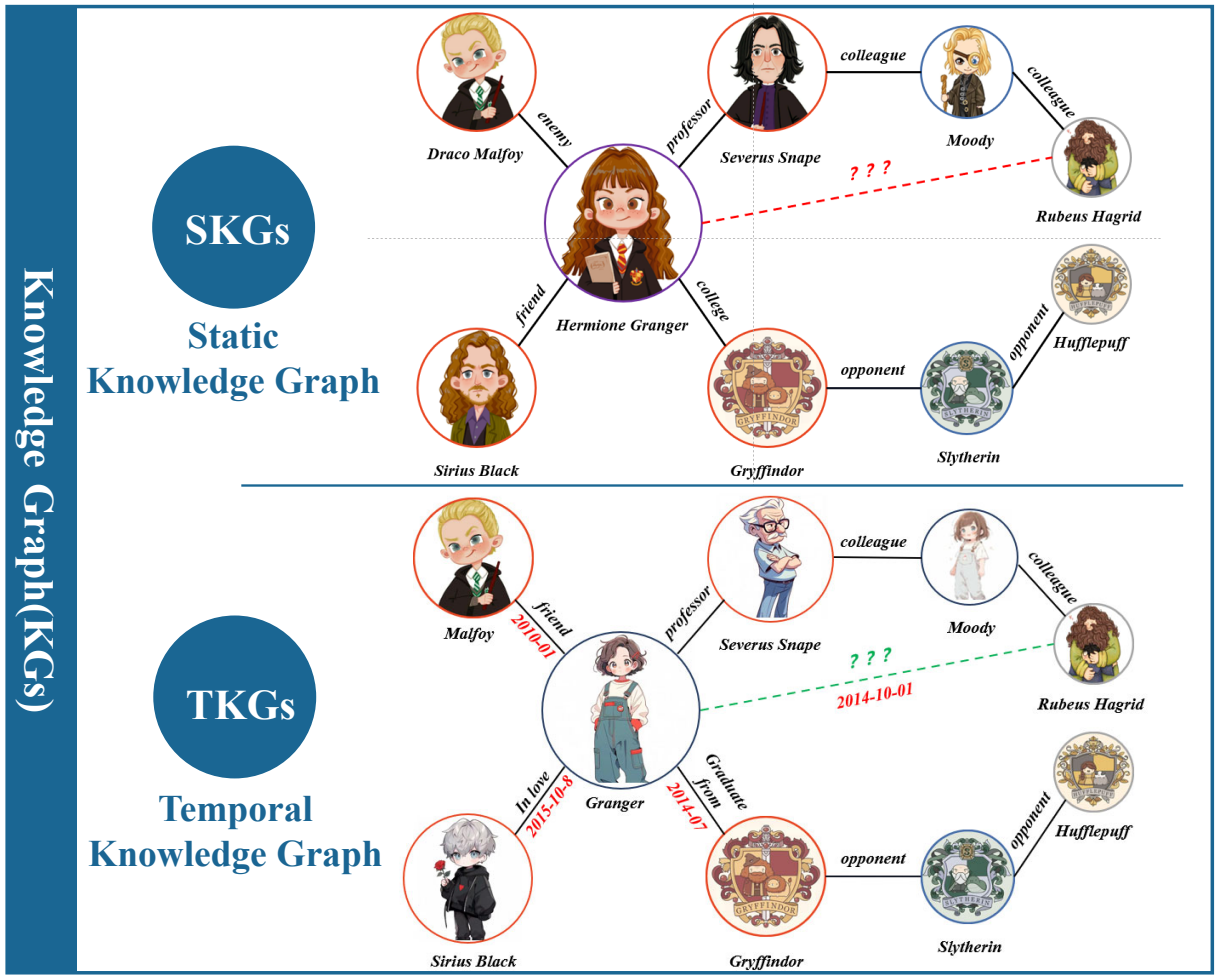
Background



ICML International Conference On Machine Learning

Large-Scale Knowledge Graph

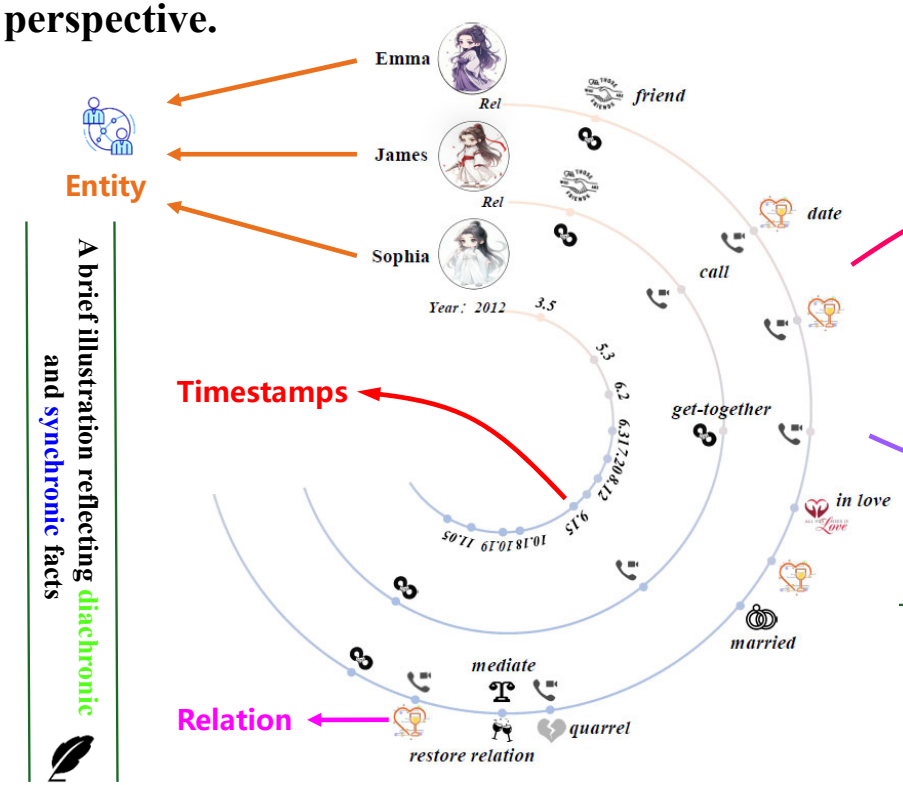
Google
Baidu
Wikidata
Yago
Bing
OpenKG

Downstream Applications

Intelligent Financial Data Analysis
Natural Language Processing
Intelligent Information Retrieval
Intelligent Prediction
Question Answering
Intelligent Healthcare

Motivation

Highlight Summary. Existing temporal knowledge graph completion research regards temporal information as supplementary, failing to observe various features and trajectories that facts can present from a temporal perspective.



Inspired by the structuralist linguist Ferdinand de Saussure's perspective on temporal contexts (diachronicity and synchronicity), the characteristics of temporalized facts can be summarized as follows:

(a) Diachronicity: Facts often exhibit varying characteristics and developmental trends across different temporal domains.

> **In March, James is friends with Emma and Sophia. By May and June, James starts dating Emma, and their relation progresses smoothly into a romantic one by July. Meanwhile, James remains ordinary friends with Sophia.**

(b) Synchronicity: In specific temporal contexts, various relations between entities often influence each other, thereby generating latent semantics.

> **In May and June, relation between Emma and James noticeably becomes closer, showing signs of ambiguity. Meanwhile, during this period, James and Sophia only have one call, remaining ordinary friends.**

The above perspectives (Synchronic Perspective and Diachronic Perspective) are not entirely independent, they often mutually depend on and serve as foundations for each other. Thus, designing a unified framework to simultaneously consider both diachronicity and synchronicity is an interesting work.

TeDS

Motivation Summary. Inspired by structuralist linguist Ferdinand de Saussure's perspective on temporal scenarios, we summarize the properties of temporalized facts as follows:

(a) Diachronicity: Facts often exhibit varying characteristics and developmental trends across different temporal domains

(b) Synchronicity: Various relations between entities often influence each other, thereby generating latent semantics.

Synchronic perception (SP)

$$Q^{\Delta}_{\tau_{sp}r} = \frac{Q_{\tau_{sp}r}}{|Q_{\tau_{sp}r}|} = \frac{a_{s\tau} + e_{s\tau}\mathbf{i} + f_{s\tau}\mathbf{j} + g_r\mathbf{k}}{\sqrt{a^2_{s\tau} + e^2_{s\tau} + f^2_{s\tau} + g^2_r}}$$

$$\mathscr{M} = Q_{r\tau_{sp}} \otimes Q^{\Delta}_{\tau_{sp}r}$$

$$Q_{sp} = Q_s \otimes \mathscr{M}^{\Delta}$$

Details of perceptron

Workflow of perceptron

Foundational to each other

Mutually dependent

Diachronic perception (DP)

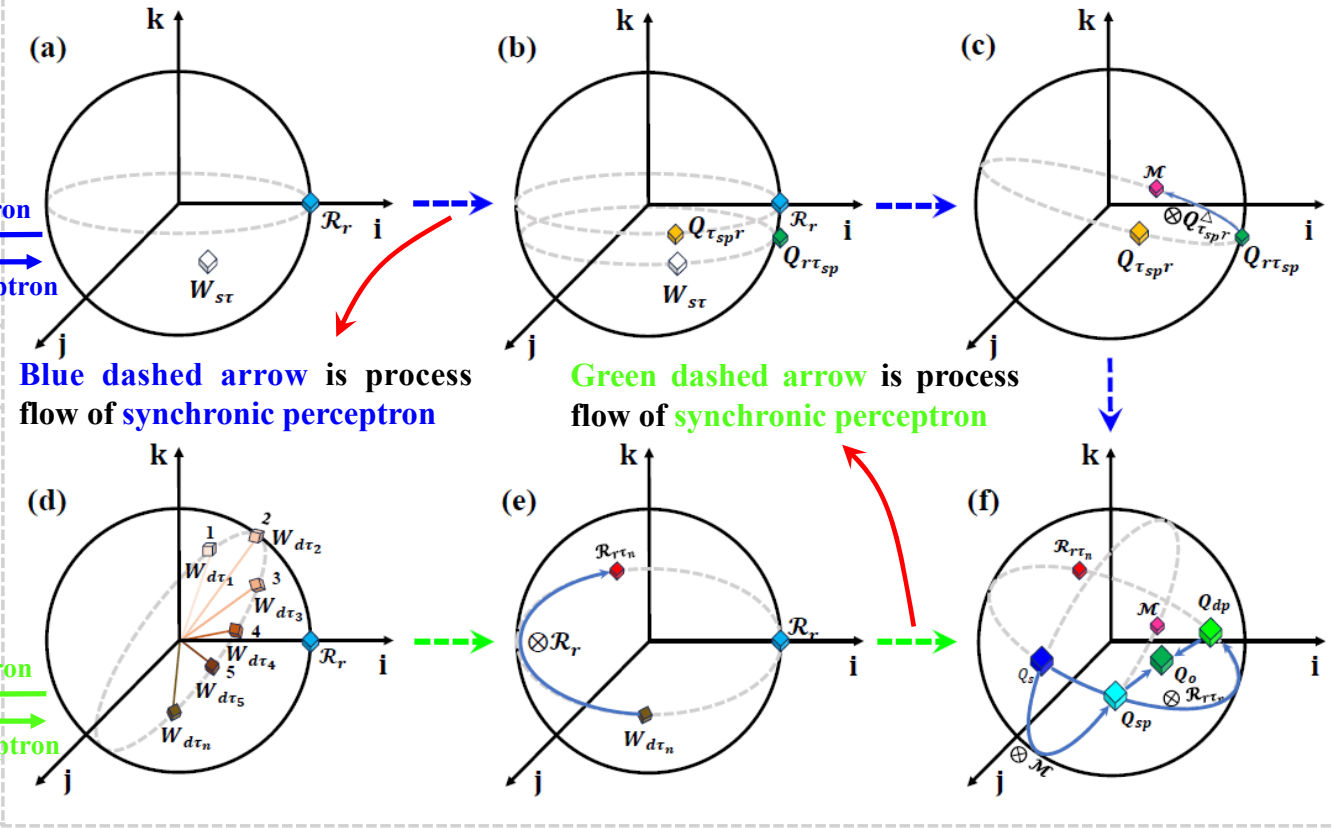
$$W_{d\tau_n} = \cos(\frac{\pi\mathscr{T}_n}{2\mathsf{T}}) + \sin(\frac{\pi\mathscr{T}_n}{2\mathsf{T}})e'\mathbf{i} + \sin(\frac{\pi\mathscr{T}_n}{2\mathsf{T}})f'\mathbf{j} + \sin(\frac{\pi\mathscr{T}_n}{2\mathsf{T}})g'\mathbf{k}$$

$$R_{r\tau_n} = W_{d\tau_n} \otimes R_r$$

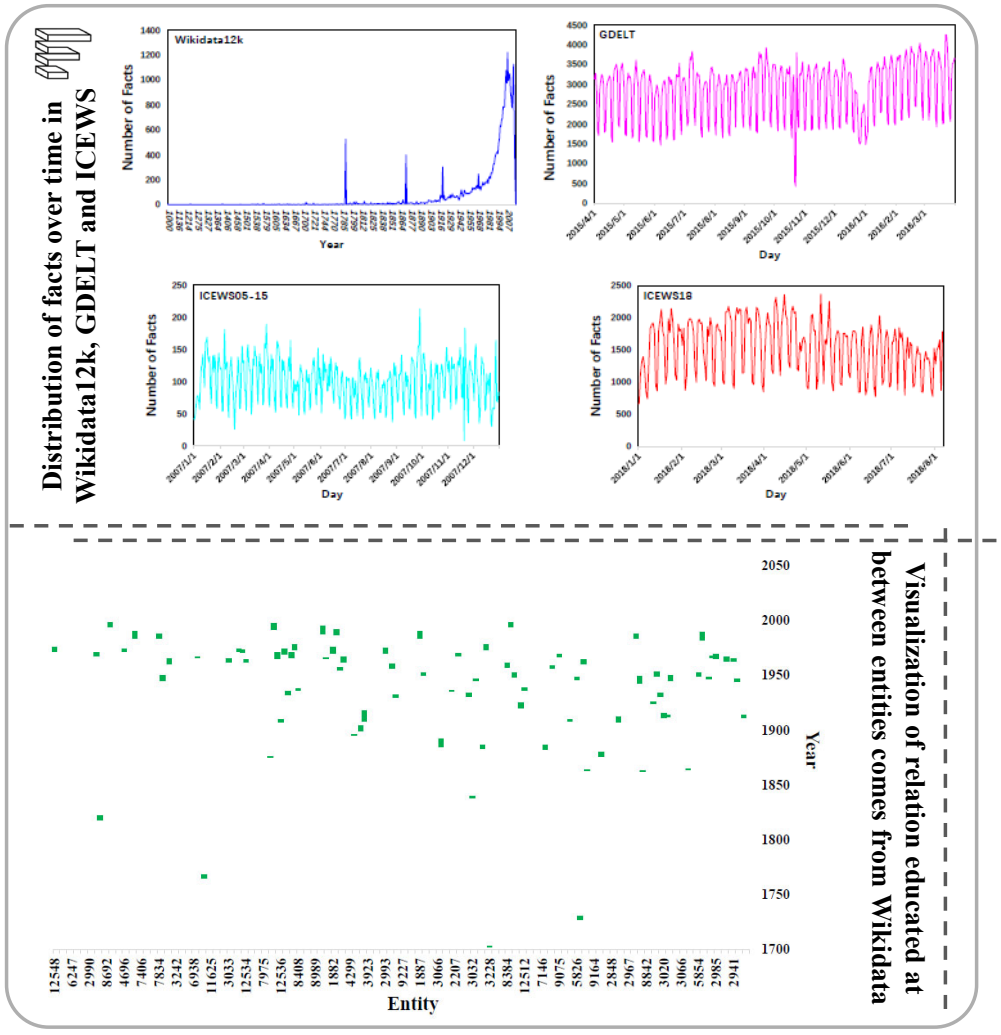
$$Q_{dp} = Q_s \otimes R^{\Delta}_{r\tau_n}$$

Details of perceptron

Workflow of perceptron



Experiments



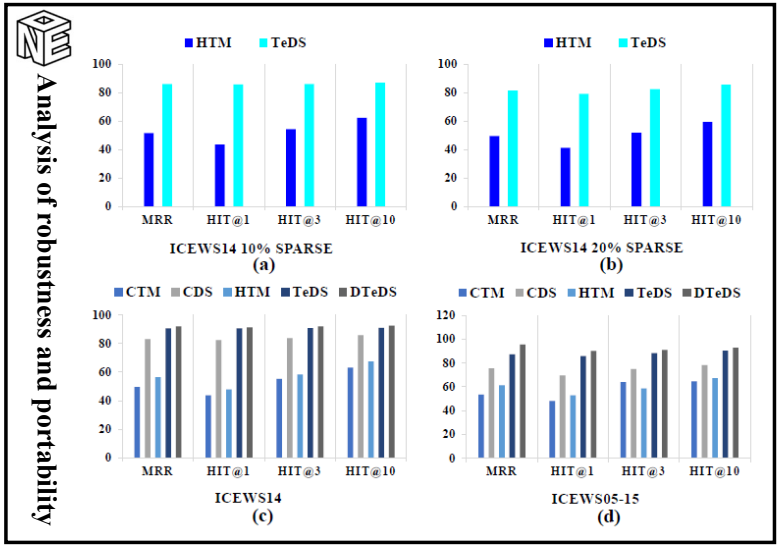
Evaluation Protocol and Baselines

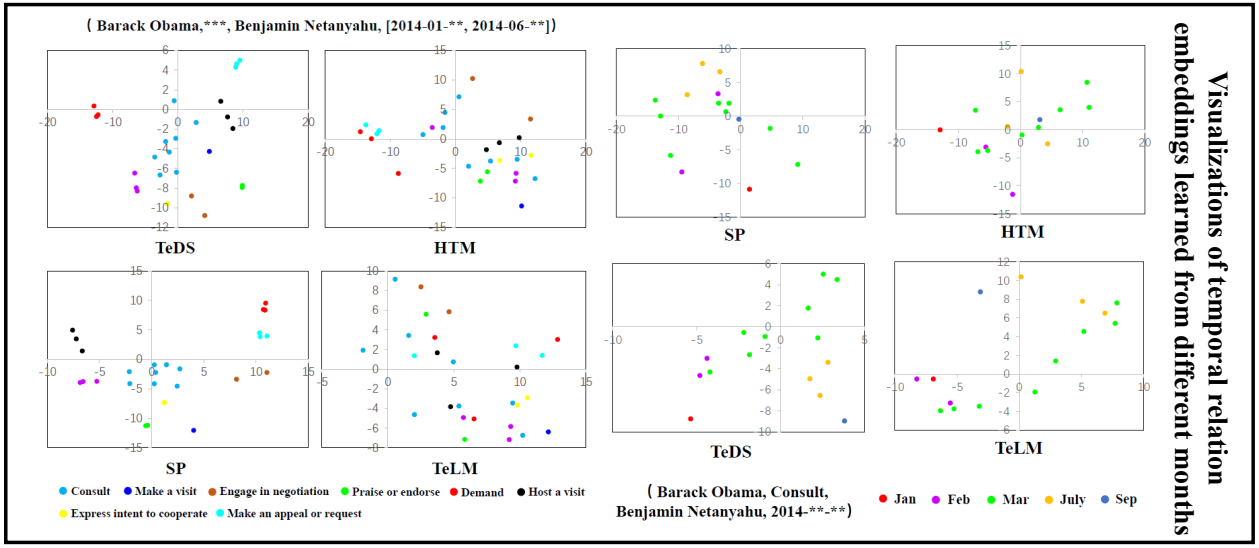
MRR *calculates average score of reciprocal ranks of the relevant KGs for a given query, where a higher MRR means better performance.* ***Hit@n*** *represents the percentage of the top n, where n ∈{1, 3, 10}, where a higher Hit@n indicates better performance.*

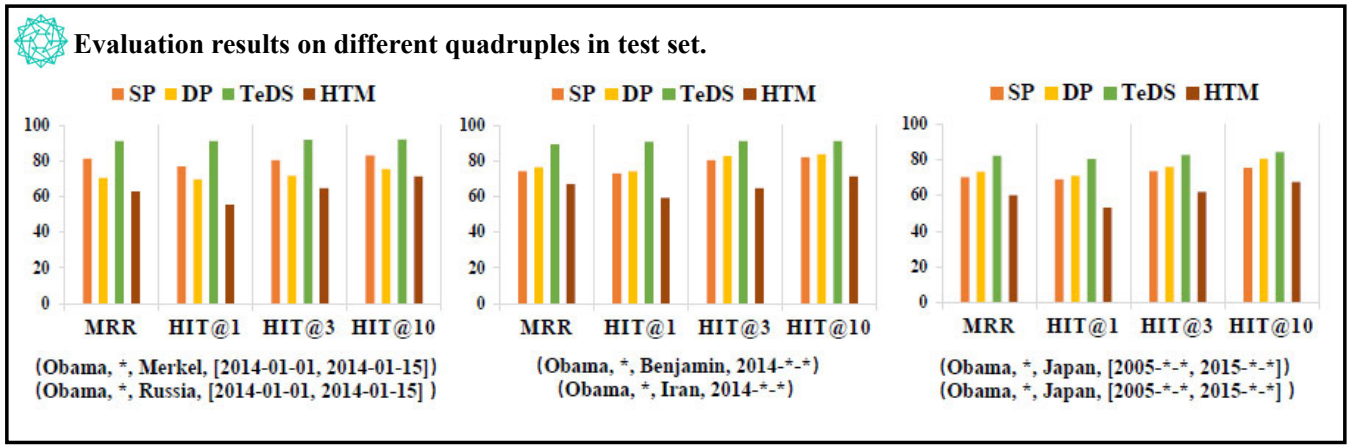
DE-SimplE (2020), HyTE (2018), TeRo (2020), TeMP-SA (2020), TNTComplEx (2020), DyERNIE (2020), ChronoR (2021), TeLM (2021), RotateQVS (2022), TBDRI (2023), BTDG (2023), TeAST (2023), TuckER-FA (2023), ODETKGE (2024), SANe (2024), MTE (2025), MDRQS(2025), Neo-TKGC (2025), GLARGCN (2025)

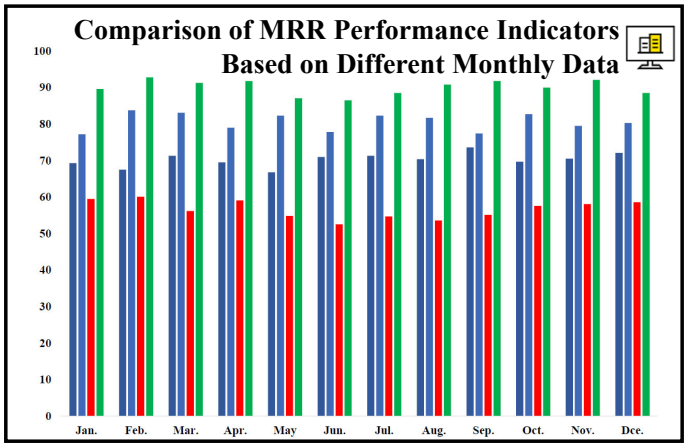
	ICEWS14	ICEWS05-15	ICEWS18
Entities	6,869	10,488	23,033
Relations	230	251	256
Facts	90,730	461,329	468,558
Period(year)	2014	2005-2015	2018
	YAGO11k	**Wikidata12k**	**GDELT**
Entities	10,623	12,544	500
Relations	10	24	20
Facts	20,507	40,621	3,419,607
Period(year)	1513-2017	1526-2020	2015-2016

Experiments









Thank you for your attention!