

# Learning Better Representations Using Auxiliary Knowledge

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# Introduction

- Representation Learning (RL) is a subfield of machine learning that focuses on learning **meaningful and compact** representations of data.
- RL is a crucial aspect of AI, helping machines to **understand and interpret** complex data inputs.
- With effective RL, AI systems can recognize patterns, make predictions, and **make decisions** based on relevant information.
- **Improving RL** can lead to more accurate and effective AI systems across a variety of applications in CV, NLP, and more.



## Enhancing RL

- **Preprocessing of input data:** Cleaning, normalizing, and transforming data.
- **Data augmentation:** Increasing the amount and diversity of training data.
- **Advanced Learning Techniques:** incorporating methods such as transfer learning, multi-task learning, adversarial training, etc.
- **Use of auxiliary knowledge:** Incorporating external knowledge, such as domain-specific information, into the RL system.



## Enhancing RL using Auxiliary Knowledge

1. **Text:** Text data, such as encyclopedias, and other natural language resources, can provide valuable information about the relationships between words, concepts, and entities.
2. **Knowledge Graphs:** Knowledge graphs represent relationships between entities as nodes and edges, providing a rich source of structured knowledge that can be used to improve RL.
3. **Similar Datasets:** Using similar datasets, such as those from related domains or tasks, can provide additional information and insights to improve RL.

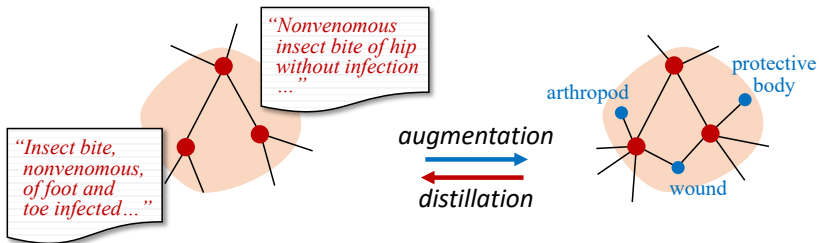


## Text as External Source of Knowledge

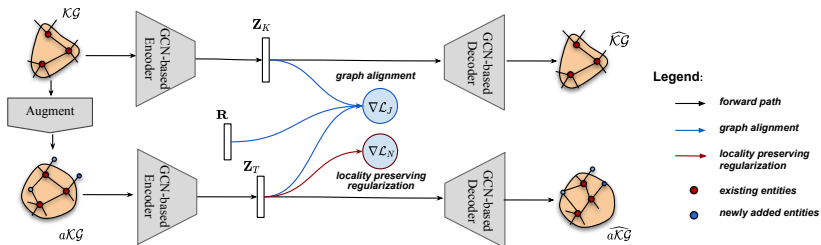
- **Knowledge Graph Embedding (KGE)**: is a type of RL that maps **entities** and **relationships** in a knowledge graph into a low-dimensional vector space.
- **Knowledge Graphs (KG)**: are a rich source of structured information but are often **sparse**, meaning that there are many missing relationships between entities.
- **External text**: can be used to improve KGE by providing additional information and insights about the relationships between entities in the KG.
- **Research Question**: How can we incorporate text into the learning process?



# Augmenting Knowledge Graph



# Proposed Method: Edge<sup>1</sup>



## Enriching KGE

1. Minimize the distance between reconstructed knowledge graph and its original version (MSE):

$$\mathcal{L}_K = \min ||\mathbf{A}_K - \hat{\mathbf{A}}_K||_2$$

2. Align **KG** and **aKG** through common entities in the embedding space (joint loss):

$$\mathcal{L}_J = ||\mathbf{Z}_K - \mathbf{RZ}_T||_2$$

3. Force textual nodes related to a target entity to be closer to that entity compared to unrelated ones (negative sampling):

$$\mathcal{L}_N = -\log(\sigma(\mathbf{z}_e^\top \mathbf{z}_t)) - \log(\sigma(-\mathbf{z}_e^\top \mathbf{z}_{t'}))$$





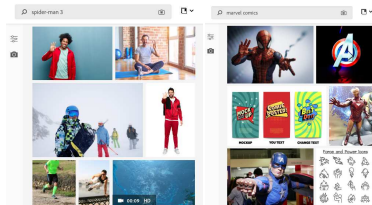
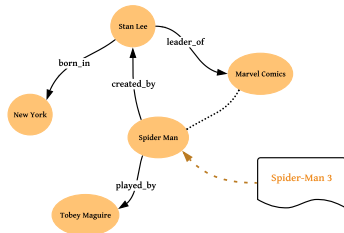
# Results

- Link prediction results on SNOMED dataset:

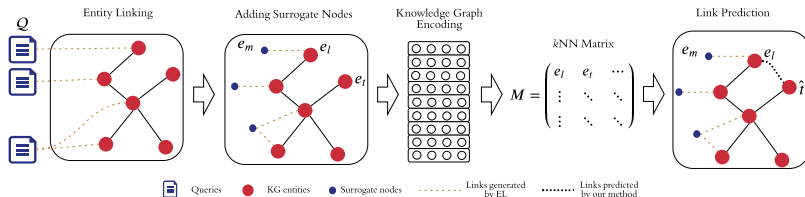
Input	Model	AUC	AP
KG	GAE	0.77	0.84
aKG	GAE	0.86	0.90
KG+aKG	EDGE	<b>0.91</b>	<b>0.94</b>

## Query Suggestion

- **Search engines** often rely on rich metadata being available for the content items.
- Some search queries might suffer from reduced relevance, i.e., **low precision**.
- **Research Question:** Can we exploit external knowledge to provide entity-oriented reformulation for queries?



## Proposed Framework<sup>2</sup>



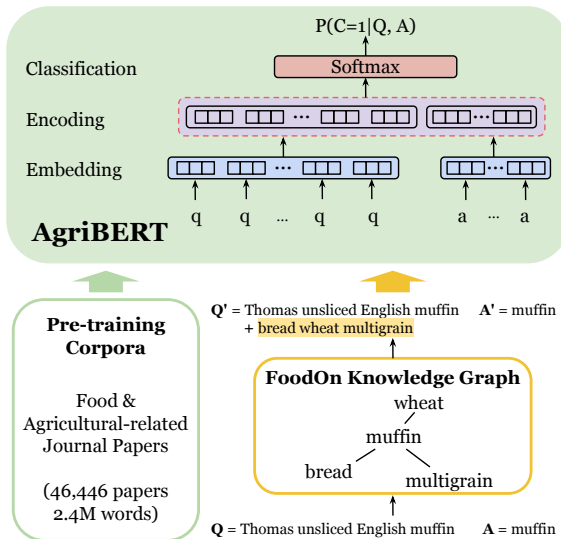
- **INPUT:** A set of queries with unsatisfactory search results.
- **OUTPUT:** A set of KG entities related to input queries.

# Semantic Matching

1. **Problem:** Matching consumer receipt data with USDA nutrition database.
2. We frame the problem as **answer selection** problem.
3. We train a language model using existing literature in agriculture domain including 2.4 million tokens (AgriBERT).
4. **Research Question:** Can we boost the performance of answer selection using an external KG?



# Framework<sup>3</sup>



# Results

Training Dataset	Model	P@1
-	kNN	14.49
-	BERT	10.88
WikiText-103	BERT+EL (Wikidata)	10.09
WikiText-103	BERT+FoodOn (n=1)	24.83
Agricultural Corpus	BERT	12.71
Agricultural Corpus	BERT+EL (Wikidata)	21.52
Agricultural Corpus	BERT+FoodOn (n=1)	47.89
Agricultural Corpus	BERT+FoodOn (n=3)	49.80
Agricultural Corpus	BERT+FoodOn (n=5)	<b>49.98</b>

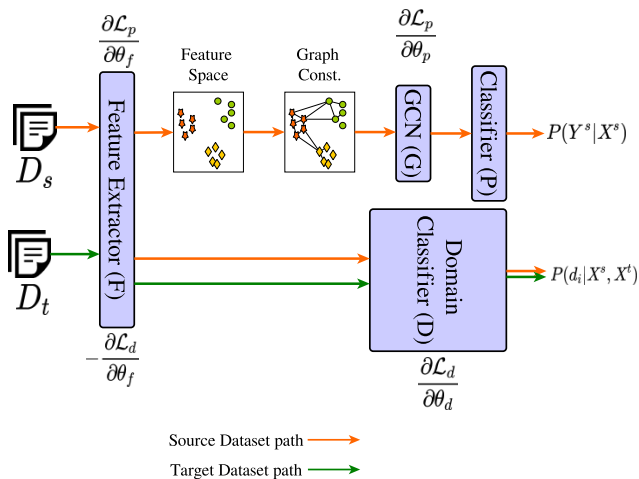


# Cross Domain Clustering

- **Problem:** Short text clustering
- **Challenges:** Unknown data distribution, topic evolution, semantic sparsity.
- **Research Question:** Can we exploit a labeled dataset to model the underlying distribution of a target dataset?



# Proposed Model<sup>4</sup>

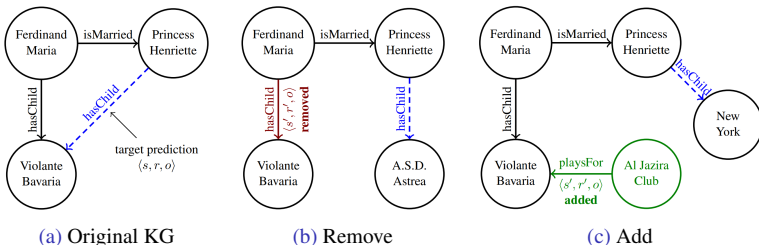


<sup>4</sup>Rezayi, Saed, et al. "XDC: Adversarial Adaptive Cross Domain short text clustering." SDM, 2023.



## Trustworthy KGE

- The embeddings generated by KGE models can be considered a **“black box”** as it is difficult to understand how they are generated and how they contribute in the performance of the model.
- Existing methods try to identify which training facts have been **most influential** to the prediction<sup>5</sup>.



<sup>5</sup>Pereshkpour, P, et al., "Investigating Robustness of Link Prediction via Adversarial Modifications." NAACL, 2019.

# Robust KGE

- To the best of my knowledge, there is no work in the area of robust KGE.
- **Research Question:** can we utilize a form of external knowledge to mitigate the effect of the attack and improve the robustness?
- Using word embedding to enhance the KGE:

$$\hat{\mathbf{e}}_i = \mathbf{e}_i + \mathbf{M}\mathbf{w}_i$$

- Other directions in trustworthy KGE include:
  - Borrowing methods from GNNs.
  - Employing other learning paradigms e.g., Reinforcement Learning.
  - Considering other areas such as Fairness in KGE.



# Conclusion

- The incorporation of auxiliary knowledge has proven to be a powerful tool for improving representation learning in AI.
- Different sources of auxiliary knowledge, including text and knowledge graphs, can be used to enhance RL in AI.
- The use of auxiliary knowledge can also be helpful in mitigating the effects of adversarial attacks on knowledge graph embeddings.

For further discussion please contact me at: [saedr@uga.edu](mailto:saedr@uga.edu)

