Research Proposal: Extensions to Rule-Guided GNN Rule-Mining on KGs

Rule Expressivity and Uncertainty Handling

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1. Introduction to Rule-Mining

1.1 Rule-Mining

- Summarizing extensional knowledge (ABox) intensionally (TBox)

$$\text{parent}(\text{Alice}, \text{Bob}) \land \text{parent}(\text{Bob}, \text{Carl}) \land \text{grandparent}(\text{Alice}, \text{Carl})$$

$$\text{parent}(\text{Hans}, \text{Iris}) \land \text{parent}(\text{Iris}, \text{Jane}) \land \text{grandparent}(\text{Hans}, \text{Jane})$$

$\Rightarrow$ New rule: $\text{grandparent}(x, z) \leftarrow \text{parent}(x, y) \land \text{parent}(y, z)$

- Historically: Symbolic approaches
  - e.g., AMIE [1]
- Knowledge Graphs: Graph Neural Networks (GNNs)
  - e.g., Relational GCN [2]

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1.2 Bibliography

- **Neuro-Symbolic (NeSy) AI**: combining the strengths and weaknesses of NNs and Logic
  - NN for mining rules
  - Logical inference using rules to increase knowledge
- Strengths:
  - Explainability vs. Black box
  - Correctness vs. Hallucinations
  - Fixed vs. variable memory and inference time
  - Data efficiency vs. huge datasets

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Bibliography

[1] L. A. Galárraga, C. Teflioudi, K. Hose, and F. Suchanek, "AMIE: Association Rule Mining under Incomplete Evidence in Ontological Knowledge Bases," in *Proceedings of the 22nd International Conference on World Wide Web*, in WWW '13. New York, NY, USA: Association for Computing Machinery, May 2013, pp. 413–422. doi: 10.1145/2488388.2488425.

[2] M. Schlichtkrull, T. N. Kipf, P. Bloem, R. van~den Berg, I. Titov, and M. Welling, "Modeling Relational Data with Graph Convolutional Networks," in *The Semantic Web*, A. Gangemi, R. Navigli, M.-E. Vidal, P. Hitzler, R. Troncy, L. Hollink, A. Tordai, and M. Alam, Eds., Cham: Springer International Publishing, 2018, pp. 593–607. doi: 10.1007/978-3-319-93417-4_38.

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