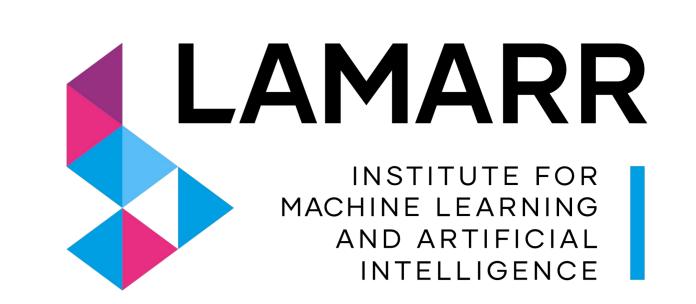# Multi-Hop Reasoning for Question Answering with Hyperbolic Representations
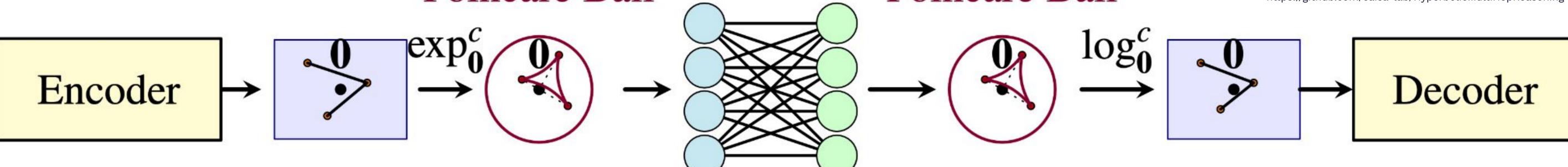
Simon Welz[1], Lucie Flek[1,2], Akbar Karimi[1,2]

[1]Bonn-Aachen International Center for Information Technology, University of Bonn, Germany
[2]Lamarr Institute for Machine Learning and Artificial Intelligence, Germany

https://github.com/caisa-lab/HyperbolicMultiHopReasoning

Encoder → $\exp_0^c$ → Poincaré Ball → Poincaré FC → Poincaré Ball → $\log_0^c$ → Decoder

Motivation

Hyperbolic Models fit hierarchical structures more naturally:

- Exponential Growth
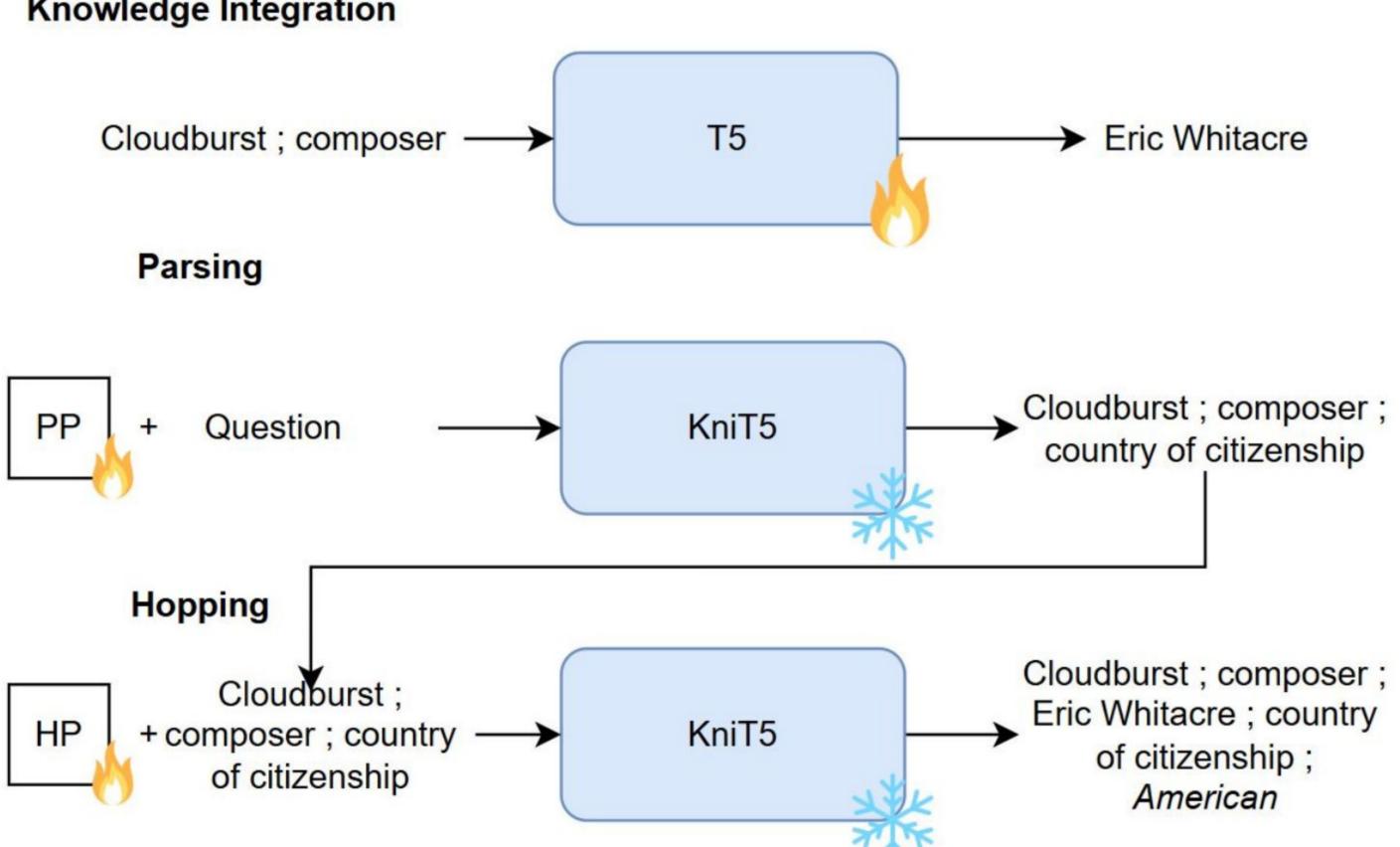- Distances modelled according to tree-structure

Research Gaps

- Lack of controlled comparison between hyperbolic and Euclidean spaces
- Curvature analysis in hyperbolic space is underexplored

Parse then Hop

Question: Which country is the composer of song Cloudburst from?

Relevant Knowledge
(Cloudburst, composer, Eric Whitacre)
(Eric Whitacre, country of citizenship, *American*)
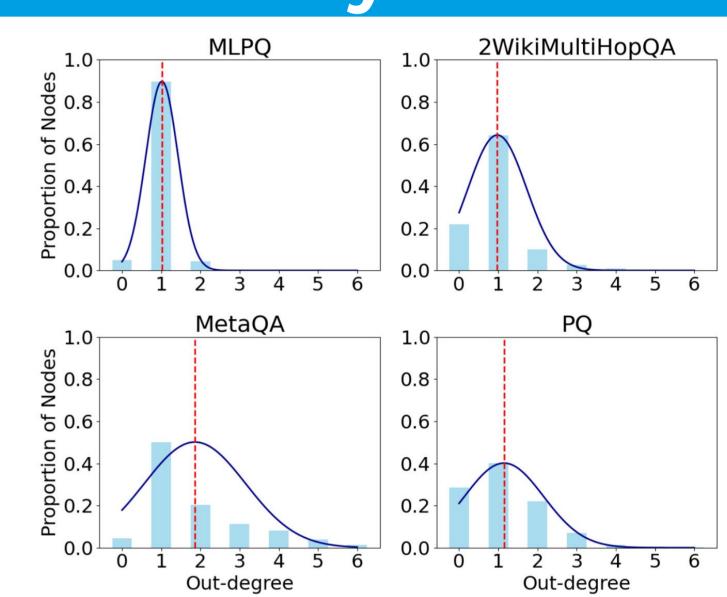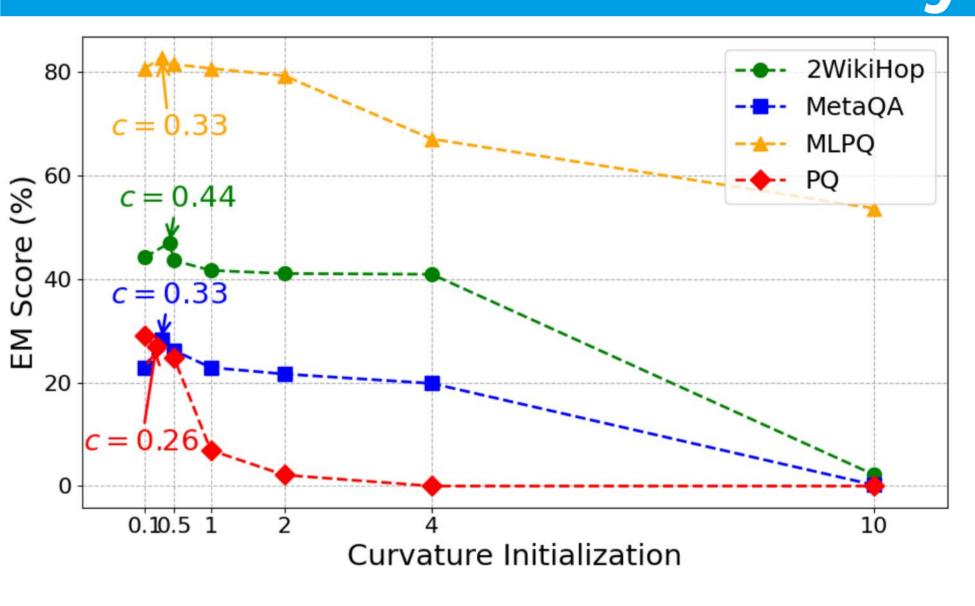
Knowledge Integration

Cloudburst ; composer → T5 → Eric Whitacre

Parsing

PP + Question → KniT5 → Cloudburst ; composer ; country of citizenship

Hopping

HP + Cloudburst ; composer ; country of citizenship → KniT5 → Cloudburst ; composer ; Eric Whitacre ; country of citizenship ; *American*

Dataset Hierarchy

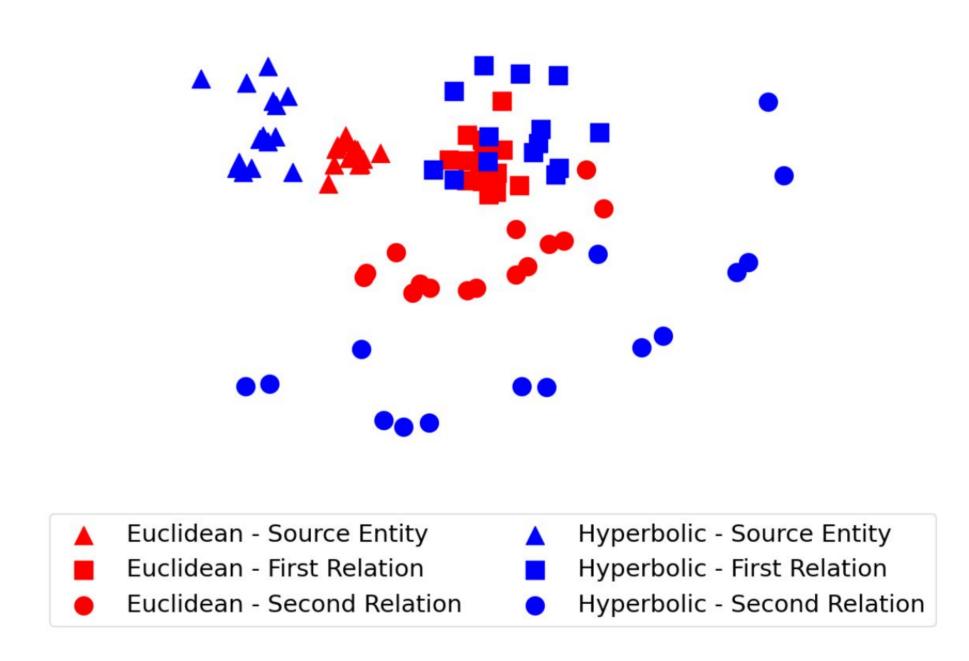More hierarchy leads to more improvement.

Curvature Analysis

Curvature initialization is crucial for performance.

Embedding Space

Hyperbolic embeddings are more spread out than Euclidean embeddings.

Main Results

Stage	Space	2WikiHop	MetaQA	MLPQ	PQ
Hopping	Euclidean	44.36	22.92	81.03	18.28
	Hyperbolic	**46.93**	**28.33**	**82.60**	**29.03**
Parsing	Euclidean	88.60	95.51	97.08	100
	Hyperbolic	**89.34**	**95.65**	**97.14**	**100**

Takeaways

- ▶ Hyperbolic space outperforms Euclidean one in multihop reasoning.
- ▶ Hierarchical datasets benefit more from hyperbolic representations.
- ▶ Curvature initialization is critical for performance.