Karlsruhe Institute of Technology

Autonome Lernende Roboter (ALR)
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Project Type

- ☑ Master Thesis
- ☐ Bachelor Thesis
- ☐ Research Project

Supervisors

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Difficulty

Algorithmic

Math

Application

Requirements

- Python and PyTorch
- ML and RL
- You like math
- *optional:* C++, knowledge in computer networks

RL for Routing Optimization with Hyperbolic Network Embeddings

Description

In Computer Networks, Routing Optimization (RO) is about finding optimal (and often shortest) routing paths between nodes. Our most recent work trains an RO policy via Swarm Reinforcement Learning (RL) [2] that uses not only the computer network's topology, but also its current load and performance statistics. In this project, we want to find out whether we can improve our routing capabilities by learning useful hyperbolic embeddings of the network state. Existing work in the networking field suggests that hyperbolic embeddings are suited for distributed routing optimization [3], and in recent years many kinds of neural networks were presented that provide such embeddings [4].

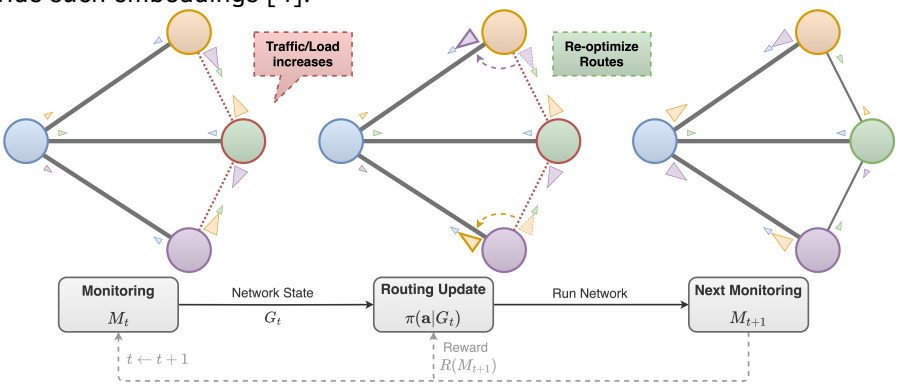

Figure 1: Situation-aware RO adjusts packet routes based on the network topology and current utilization/load to avoid congestion, delay and packet drops.

We would like to combine these advances and show that the hyperbolic embeddings help in finding optimal routes. We build upon our existing framework for RL experiments on RO in the network simulator ns-3 [1] and extend it to use hyperbolic Neural Network architectures (GNN/MLP) like the ones mentioned in [4].

Tasks

- Literature Research: Acquiring a comprehensive understanding of Riemannian geometry, hyperbolic neural networks and routing optimization; Specifying the research gap we aim to fill; Selecting a model architecture to continue with.
- Implementation of Hyperbolic Routing Policy into our framework; Adjusting RL algorithm components like losses so that the embedding is learned properly.
- Embedding Visualization. With Hyperbolic embeddings in particular it is useful to understand how the network makes its decisions. Therefore, we shall implement an embedding visualization that is intuitive to humans.
- Evaluation of the hyperbolic embeddings in our framework, comparing against euclidean embeddings and heuristic approaches.

References

[1] Thomas R Henderson, Mathieu Lacage, and George F Riley. Network Simulations with the ns-3 Simulator. *SIGCOMM demonstration*, 14(14):527, 2008.

[2] Maximilian Hüttenrauch, Šošić Adrian, and Gerhard Neumann. Deep reinforcement learning for swarm systems. *Journal of Machine Learning Research*, 20(54):1–31, 2019.

[3] Fragkiskos Papadopoulos, Dmitri Krioukov, Marian Boguna, and Amin Vahdat. Greedy forwarding in dynamic scale-free networks embedded in hyperbolic metric spaces. In *2010 Proceedings IEEE INFOCOM*, pages 1–9, 2010.

[4] Wei Peng, Tuomas Varanka, Abdelrahman Mostafa, Henglin Shi, and Guoying Zhao. Hyperbolic deep neural networks: A survey. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, 44(12):10023–10044, 2022.