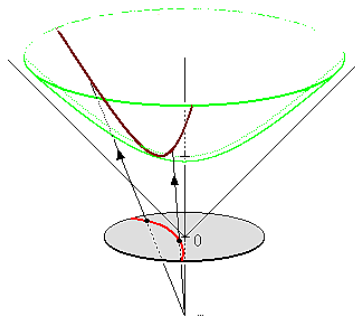# Hyperbolic Neural Networks

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Skoltech

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Preliminaries

Hyperboloid $\{(\xi, \tau): \ \tau^2 - \|\xi\|^2 = R^{n+1}\}$ is isometric to Poincare ball of radius R.

Cool facts about

Facts about negative curvature:

1. Trees of constant branching factor are spaces of negative curvature and can be embedded in a Poincare ball

2. Volume grows exponentially with distance from ball center
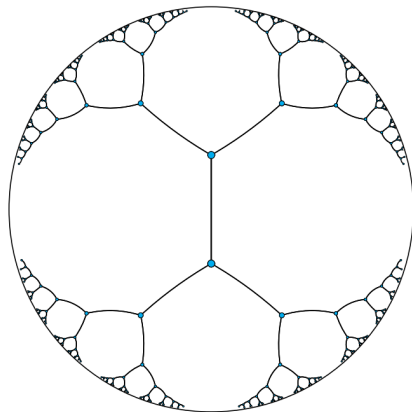
3. Geodesics and barycentres are unique

Figure: Embedding example: Poincare Model

Hyperbolic spaces in the wild

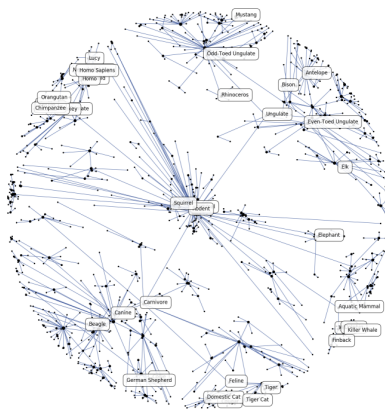Bright papers from Facebook showed that hyperbolic spaces are good for language models

Figure: Poincar Embeddings for Learning Hierarchical Representations

Utilizing Embeddings

Further accounting for negative curvature of text and graph embeddings, Octavian-Eugen Ganea propose Hyperbolic RNNs.

Challenges:

- Hyperbolic RNN cell – how to mimic Euclidian math in hyperbolic space?
- Parameters on the Poincare Disc – how to perform SGD?

TLDR [1]: do logmap-update-expmap (cf. Gyrovector spaces and Riemannian optimization)

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[1]We got but 15 minutes

Challenges

- Authors' code: `tensorflow`
- Our tool of choice: `pytorch`
- No Riemannian optimization out of the box
- No optimized implementation for hyperbolic rnn
- Training is numerically unstable with `float32`

Evaluation on toy data:

- Vocabulary size: 100
- Sentences are short
- Train/Validation/Test set: 50k/10k/10k examples
- Takes a day of training or even more to obtain good results

Our contribution: `Geoopt` & Hyperbolic GRU

We started an open source project `Geoopt`. Our contributers include folks from Facebook Research and Skoltech. We already got cited in `http://hyperbolicdeeplearning.com` and some other media

Visitors

633 Views   61 Unique visitors
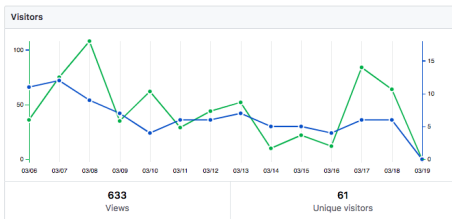
Referring sites		
Site	**Views**	**Unique visitors**
github.com	97	23
Google	26	7
hyperbolicdeeplearning.c...	23	5
openreview.net	18	6
ritchieng.com	1	1
newkozlukov.gitlab.io	1	1

Popular content		
Content	**Views**	**Unique visitors**
GitHub - geoopt/geoopt: ...	135	52
Pull Requests	48	8
Poincare ball model by fer...	40	6
geoopt/geoopt at master	31	14
Normal sampling by Code...	28	4
Stargazers	19	2

`github.com/geoopt/geoopt`

geoopt

pypi v0.0.1   docs passing   build passing   coverage 67%   code style black   chat on gitter

Manifold aware pytorch.optim .

Unofficial implementation for "Riemannian Adaptive Optimization Methods" ICLR2019 and more.

Installation

Make sure you have pytorch>=1.0.0 installed

There are two ways to install geoopt:

1. GitHub (preferred so far) due to active development

```
pip install git+https://github.com/geoopt/geoopt.git
```

Geoopt

The major part of Skoltech project was devoted to implement and document a **Poincare ball model for Geoopt**. It already allows to use Adam, Amsgrad, SGD, Nesterov optimization methods.

Current status:

- **Implementation:** 100% test coverage for Poincare math

  ✓ Tests passed: 580 of 580 tests – 4 s 115 ms

- **Documentation:** waiting a review from Facebook/Skoltech. Preview available here: `https://geoopt.readthedocs.io/en/Poincare/extended/Poincare.html`

Plans:

- Continue the project, **new contributors are welcome!**

Our Hyperbolic GRU in pytorch

Hyperbolic GRU was another part of our Skoltech project. Available at `https://github.com/ferrine/hyrnn`

Status:

- Same API as native pytorch GRU:
    - Variable sequence length
    - Multilayer
- Reproduced authors' results
- `RAdam` performs better than `RSGD`

Plans:

- Test coverage for Hyperbolic GRU
- Learn pytorch-cpp to optimize its runtime
- Adapt for `float32`