McTorch, a manifold optimization library for deep learning

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Our interest is the optimization problem of the form

$$\min_{x \in \mathbb{R}^n} f(x)$$
subject to
$$x^\top x = 1.$$

Assume that $f$ is differentiable.
Manifold optimization generalizes unconstrained optimization to manifolds.

Solving
\[ \min_{x \in \mathcal{M}} f(x), \]

where \( \mathcal{M} =: \{ x \in \mathbb{R}^n : x^\top x = 1 \} \)

is equivalent to

**Unconstrained optimization** over the (nonlinear) manifold \( \mathcal{M} \).
Applications
Principal components analysis (PCA) is on manifold of orthogonal matrices

Stiefel manifold models such orthogonal constraints
Recommender systems: low-rank matrix / tensor modeling

The Grassmann manifold is used to model such constraints

\[ (n + m - r) r, \quad r \ll (m, n) \]
Learning continuous representations of hierarchies

Hyperbolic manifold is used to model hypernymy relationships

Figure from mnick.github.io.
Metric learning

Symmetric positive definite matrices form a manifold.
Most Euclidean optimization algorithms generalize well to manifolds

- Conjugate gradients.
- BFGS and Quasi-Newton methods.
- Non-smooth optimization on manifolds.
- Stochastic gradients w/o variance reduction.
- Preconditioning on manifolds.
There exist other independent toolboxes for optimization on manifolds

- Pymanopt: a Python toolbox for manifold optimization.


- Geomstats: a Python package for computations and statistics on manifolds.

- McTorch: a PyTorch extension to do manifold optimization for deep learning applications painlessly.
To know more about McTorch, visit our demo.
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