

# Manopt, a toolbox for optimization on manifolds

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## *Demo proposal for TCMM 2014*

Submitted by Nicolas Boumal (UCLouvain) and Bamdev Mishra (University of Liège), July 30.

Dear organizers of the TCMM 2014 workshop,

We would like to propose a demo about Manopt: an open source Matlab toolbox: [www.manopt.org](http://www.manopt.org).

Manopt is designed to help using and developing algorithms for optimization on manifolds (also known as Riemannian optimization). Riemannian optimization constitutes a class of optimization problems whereby one seeks to minimize an objective function over a smooth Riemannian manifold. Examples of typical manifolds arising in applications (many of which are machine learning applications) include the Stiefel manifold (orthonormal matrices), the Grassmann manifold (the space of linear subspaces), the group of rotations, the set of fixed (low) rank matrices (symmetric or not), the cone of strictly positive definite matrices, correlation matrices... This is not exhaustive.

The core idea of Riemannian optimization is to work *intrinsically* on the smooth search space. In this way, the problem looks “as if” there were no constraints, and one recovers most results from standard unconstrained nonlinear optimization theory. Manopt is an implementation of a good portion of the current state of affairs in this vein, much of which is described in the monograph “*Optimization algorithms on matrix manifolds*”, by Absil et al. (2008): <http://press.princeton.edu/chapters/absil/>.

The toolbox is recent (it was first released early in 2013). It is described in a recent paper published in the machine learning community: “*Manopt: a Matlab toolbox for optimization on manifolds*”, by Boumal, Mishra, Absil and Sepulchre, JMLR 2014. It is well documented in-code and on the website (including a tutorial, a manual, a reference and example scripts) and ships with a variety of built-in algorithms and manifold descriptions. These combined reasons earned Manopt the 2014 ORBEL prize for OR software development. It has already been successfully used in multiple research projects, where it helped accelerate research and outperform competing algorithms. The user base is still modest, but we are bit by bit building a community, among other things via a forum on the project’s website.

A number of software packages exist for optimization on manifolds, but none is as comprehensive as Manopt. Most packages focus on one or two specific manifolds (typically, Stiefel or Grassmann). Some packages propose one generic solver (optimization algorithm), but without built-in collection of manifold implementations. Such packages tend to be limited in their usage scope and are targeted at specialists. On the contrary, Manopt ships with multiple solvers, multiple manifolds and numerous helper tools (including some debugging helpers). The documentation and examples aim to get beginners up to speed in a short time. Advanced features aim to raise the interest of specialists too.

It is our hope that if we have the opportunity to showcase Manopt as a demo at TCMM, this would contribute to increase interest in Riemannian optimization in the machine learning community and that

it could help expand our user base. A more long-term goal is to push Manopt as a platform where all Riemannian optimization related research can come together.

## Format of the demonstration

Our demo will include two main components.

1. A general presentation part, where we will introduce the generic concept of Riemannian optimization and illustrate its applicability in machine learning through examples (see below). To support us in this, we will bring a poster, a slideshow and hopefully also a tutorial video (in the making), both running on large screens.
2. A hands-on “live” part, where we will use a whiteboard (or equivalent) to define an optimization problem mathematically, go through the (very limited, and elementary) mathematical manipulations needed, then switch over to a Matlab running on a large screen to implement the described problem (live) in Manopt and run it. This will give our visitors the opportunity to see the whole chain of actions involved. This will also give us the opportunity to show how one can use the online documentation on our website to assist in this task, as well as the helpful debugging tools. This part can also serve to compare Manopt with, for example, Matlab’s built-in optimization toolbox, which could be able to handle some of the problems we address.

Examples of machine learning related problems that can be discussed include: low-rank matrix completion, sensor network localization, sparse PCA, robust PCA, eigenvector and singular vector decompositions, Karcher mean computations, the generalized Procrustes problem...

Of course, the demo-booth format is also perfect for free-form discussions, adapted to each visitor’s specific interests.

## Equipment description

The presenters will come with personal laptops and a poster. If possible, it would be great to have at our disposal:

- One (two if possible) large screen(s) to which a computer would be connected to display a fancy slideshow/tutorial video and demonstrate live usage of the toolbox.
- A panel for the poster (A0 format, portrait: the typical conference format).
- A whiteboard, or other “presentation device” would be great.
- Table(s) and chairs that can sit two people with laptops and some spare space for papers.

Thank you very much for your time and consideration,

Yours sincerely,

Nicolas Boumal and Bamdev Mishra