Introduction to Mathematical Optimization

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Kevin Carlberg

- ▶ *Background*
  - ▶ PhD Aeronautics & Astronautics, 2011, Stanford University (PhD Minor in CME)
  - ▶ Harry S Truman Postdoctoral Fellow, Sandia National Laboratories, 2011–2014
  - ▶ Principal Member of Technical Staff, Sandia National Laboratories, 2014–2019
  - ▶ Distinguished Member of Technical Staff, Sandia National Laboratories, 2019–2019
  - ▶ Research Scientist, Facebook Research, 2019–
- ▶ *Research interests*: machine learning, computational physics, high-performance computing, model reduction, uncertainty quantification, numerical optimization, Krylov-subspace methods, time-parallel methods

Pre-course feedback

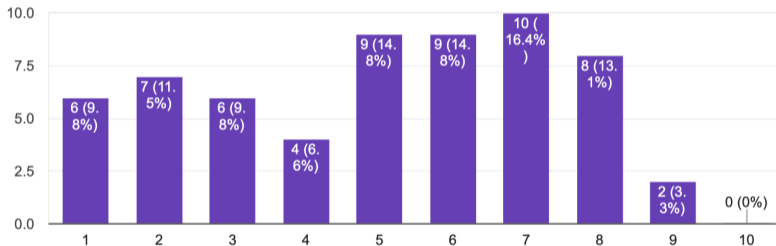**Rate your current knowledge of mathematical optimization**

61 responses
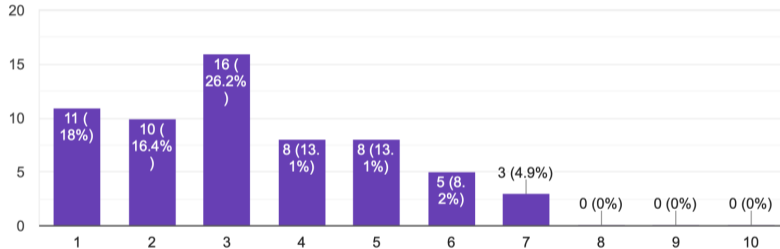
- ▶ I will not assume you have any previous knowledge
- ▶ Yet, we will cover some advanced topics and tools for the 5-7 people

Pre-course feedback
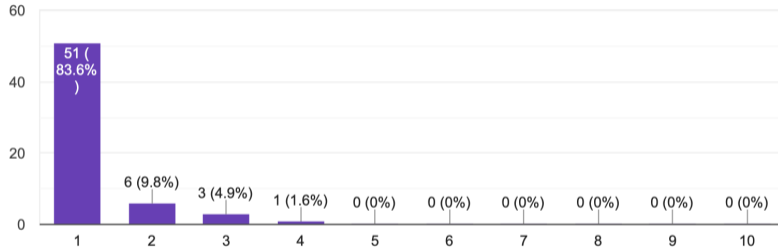
Rate your experience level with Python

61 responses

▶ Provided Jupyter notebooks that can be run without experience with Python
▶ Those with Python experience can quickly figure out how to use optimization tools

Pre-course feedback

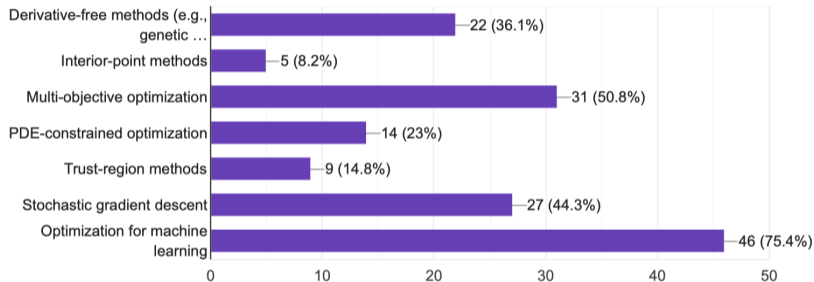### Rate your experience level with CVXPY

61 responses

- ▶ No previous knowledge is needed
- ▶ CVXPY has a shallow learning curve: designed to allow you to ''express your problem in a natural way''

Pre-course feedback

Which special topics most interest you?

61 responses

- We will briefly cover optimization aspects of machine learning
  - stochastic gradient descent
  - neural networks
  - distributed optimization

Pre-course feedback

▶ Lots of interest in machine learning, Python, general knowledge

Course materials

Add the shared folder to your account:

- ▶ Go to drive.google.com and log in with your Google account
- ▶ Go to https://tinyurl.com/yye7vlfx to access the shared Google Drive folder
- ▶ Click on "Introduction to Mathematical Optimization 2019" > "Add to My Drive".

Try the notebooks:

- ▶ In Google Drive, go to "Introduction to Mathematical Optimization 2019" > "Notebooks"
- ▶ Double click any notebook; click "Open with Google Colaboratory" at the top
- ▶ You now have three options:
    1. *Look at the notebook and its output*: Simply scroll around.
    2. *Interact with the notebook*: Click on "Open in playground" at the top left to modify the notebook and interact with it. Because this remains part of the original folder, you cannot make permanent changes to the notebook.
    3. *Make a copy of the notebook*: Click on "Copy to Drive" at the top, which will create a copy in "My Drive" > "Colab Notebooks". This is your own separate copy, and you can make permanent changes to the notebook.

Outline

Session 1: 9:00am–10:30am

- ▶ Introduction to optimization (2_introduction.pdf)
- ▶ Unconstrained optimization (3_unconstrained.pdf)

Session 2: 10:45am–12:00pm

- ▶ Optimization in Python (4_optimization-in-python.pdf)
- ▶ Constrained optimization (5_constrained.pdf)

Session 3: 2:00pm–3:15pm

- ▶ Optimization for machine learning (6_optimization-for-ml.pdf)

Session 4: 3:30pm–4:45pm

- ▶ Convex optimization (7_convexity.pdf)
- ▶ Convex-optimization examples (8_modeling.pdf)

References

- ▶ These slides
  - ▶ A lot of content
  - ▶ Very verbose to make self-contained
- ▶ J. Nocedal and S. J. Wright. *Numerical Optimization*, Springer, 1999.
- ▶ S. Boyd and L. Vadenberghe. *Convex Optimization*, Cambridge University Press, 2004. (available online)
  - ▶ Excellent lectures by S. Boyd online
  - ▶ Class notes and lectures for EE364a, EE364b online
  - ▶ CVX101 MOOC
- ▶ P.E. Gill, W. Murray, and M.H. Wright, *Practical Optimization*, London, Academic Press, 1981.
- ▶ Bottou, L., Curtis, F.E. and Nocedal, J., 2018. Optimization methods for large-scale machine learning. SIAM Review, 60(2), pp.223-311. (available on the arXiv)
  - ▶ Advanced recent review article

ICME at Stanford
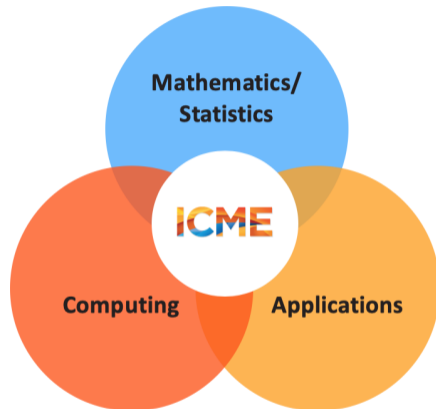
- ▶ **Hub at Stanford**: Critical inter-disciplinary field using advanced mathematics and computing to address complex problems

55+ affiliated faculty across Stanford
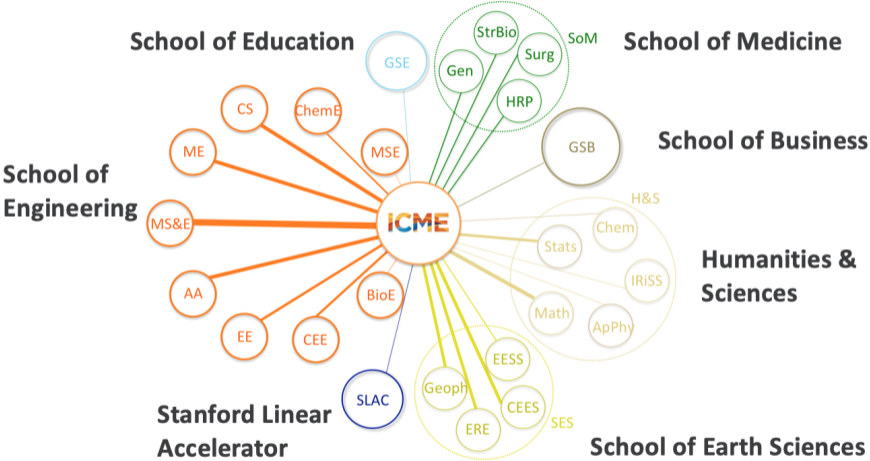
150+ MS and PhD students

- ▶ Degre-granting graduate program
- ▶ Over 60 courses offered annually

ICME Industry Affiliate Partnership Program

- ▶ Concierge-style recruiting of ICME students
- ▶ Invitations to quarterly events (roundtables, symposia, seminars)
- ▶ Professional development in data science & machine learning
- ▶ Faculty liaison
- ▶ State-of-the-art facilities
- ▶ Discounts at the summer workshops
- ▶ Email Karen Matthys (`kmatthys@stanford.edu`) if interested in participating
- ▶ https://icme.stanford.edu/partnership-programs