Conclusions and Projects

Chee Wei Tan

Convex Optimization and its Applications to Computer Science

Outline

- Review of Topics
- What We have Covered, Learned and not Covered
- Optimization Mentality
- Projects
- Conclusions

What We Aim

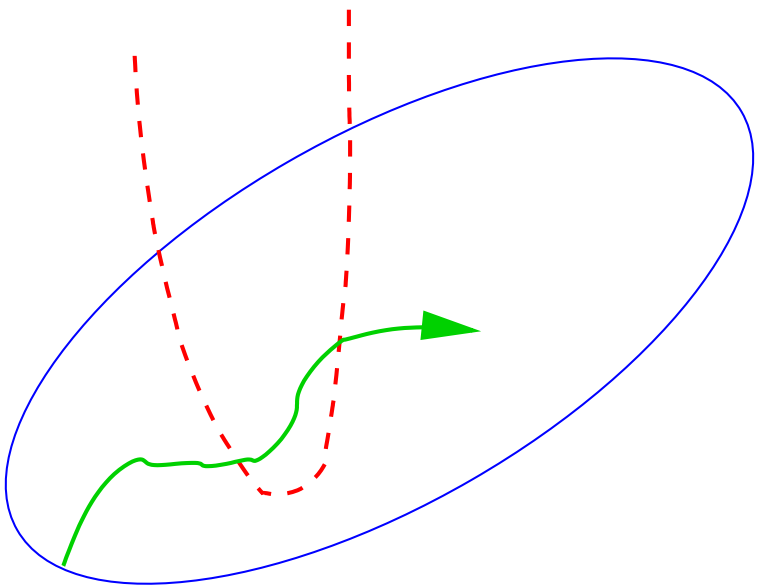
1. Provide students with the tools and mentality of optimization.

2. Present classic and recent research topics in optimization.

3. Introduce the tools just in time for the application topics.

4. Train the ability to do original research in academia or industry.

Our Starting Point



$$\begin{array}{ll} \text{minimize} & f(x) \\ \text{subject to} & x \in C \end{array}$$

Optimization variables: x. Constant parameters describe objective function f and constraint set C

What We Have Covered

- Convex optimization: Local optimality implies global optimality, LP, QP, QCQP, SOCP, SDP, DCP, GP, GGP, SP
- Weak and strong duality
  - Bounding the optimal value
  - Certificates of optimality
  - Decomposition
  - Algorithm design
- Optimization algorithms: Interior-point, Gradient, Newton, Fixed-point iterative methods, First-order method, Fast/Distributed
- Software tools like CVX for high-level model prototyping and rapid programming synthesis

What We Learned

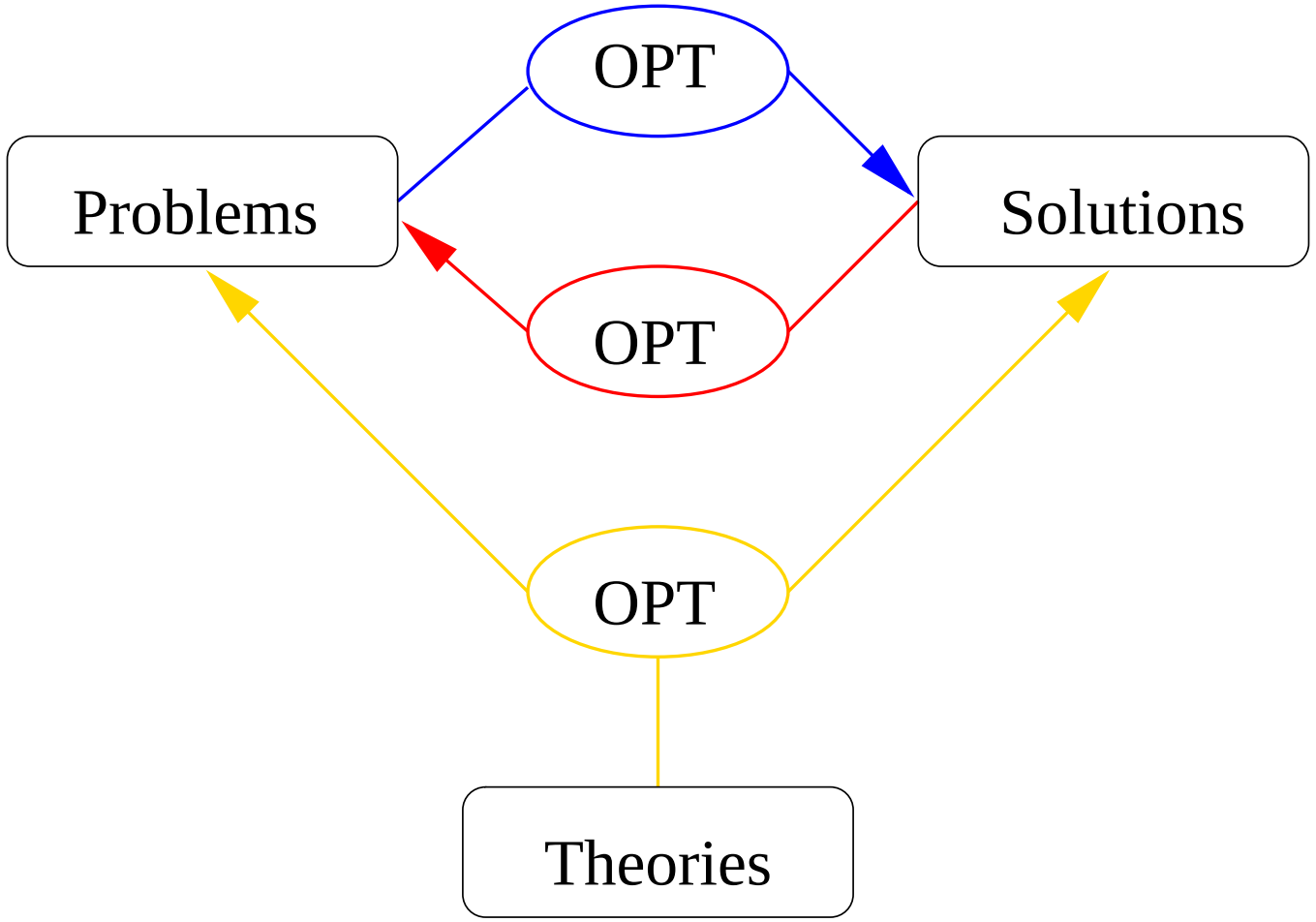
- Start with simple problems and assumptions, develop intuition.
- Techniques
  - Duality and KKT (optimization workhorse): Primal $\leftrightarrow$ Dual
  - Transformation trick: Reformulation, smoothing by LP, GP
  - Convex decomposition: primal-dual decomposition, NUM
  - Hidden convexity: GP, SP, wireless network optimization
  - Convex relaxation: Max-Cut, GP, SDP, nonconvex QP
  - Algorithm design and rapid prototyping with software
- Survey a wide range of different applications and masters[1]: Learn tricks from others and apply them to your own.

[1] Cauchy, Euler, Gauss, Lagrange, Newton, Perron, Frobenius, Dantzig, Karush, Kuhn, Tucker, Kantorovich, Bellman, Ky Fan, Duffin, Peterson, Zener, Karmarkar, Boyd among others we have talked about in Lecture

What We Didn't Cover

- Advanced Interior Point methods
- Proximal method
- Successive convex approximation, ϵ-suboptimality
- Smoothing technique and optimal first-order method
- Congugate gradient descent, accelerated coordinate descent
- Gomory's cutting plane and Kelley's method
- Convex optimization treatment of many interesting nonconvex problems in other engineering and computer science applications

Optimization Mentality



Optimization as a language, as an engineering system, as a rule for algorithm design, as a unifying principle

Projects

- 75-character Matlab LP solver challenge
- Disciplined Convex Programming, fastest QP solver
- Optimization software for big data, large graphs, Gamma function
- Statistical inference: Maximum likelihood estimation, sports rating, convex regression
- Fitting a simple neural network, generative adversarial networks, deep learning
- GP and its applications: Digital circuit optimization, wireless network optimization
- Large-scale applications to Internet, machine learning and social networks

Conclusions

"A course is not about what we have covered, but what *you* have *uncovered*."[2]

To Everyone in this course, you have been amazing!

[2] What I've learned from Professor Mung Chiang.