Heuristic Optimization

Lecture 9

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Continuous vs. Discrete

What Optimization Problems do you know?

Give three discrete optimizations problems (possibly from this course) and three continuous optimization problems (possibly not from this course).

What Optimization Algorithms do you know?

Give two discrete optimizations algorithms (possibly from this course) and two continuous optimization algorithms (from this course).

How Do We Optimize?

- Consider the following optimization problem:

$$\text{maximize:} \quad -x^3 + 10x^2 + 6, \text{subject to } x \geq 0.$$

- How do you solve this?
- Set derivative to 0 and solve: $x = 20/3$.
- Can we deal with more variables?

$$\text{maximize:} \quad -5x^2 + 3xy - 6y^2 + 37x.$$

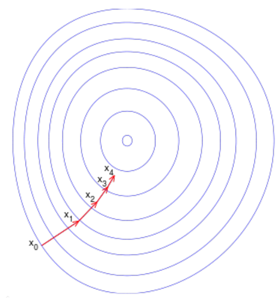
- Set both partial derivatives to 0 and solve: $(x, y) = (4, 1)$.

Using Gradient Information

- Newton's Method
  - Need second derivatives (costly!).
  - Hessian (matrix with all pairwise second derivatives).
- Gradient Descent
  - Hill Climbing (Gradient Ascent).
  - Need first derivatives (Jacobian).

There are many other methods that

- use gradient information;
- approach some local optimum;
- employ step size control (learning rate).

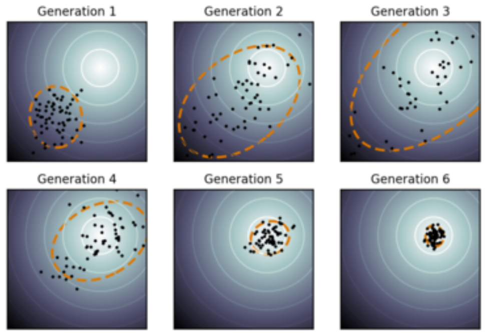


Gradient-Free Optimization

- What if we don't know the gradient?
- This is the true black-box setting.
- Evolutionary Strategies (ES)
  - estimate the gradient by sampling offspring;
  - in a sense simulate the gradient descent method;
  - several variations make these algorithms very robust.

CMA-ES (Covariance Matrix Adaptation)

- very popular;
- many implementations available;
- maintains a multivariate Gaussian distribution over the search space;
- try to approach the optimum with the center of the Gaussian;
- variance corresponds to step size.



PSO (Particle Swarm Optimization)

- most popular swarm optimizer (maybe a tie with ACO);
- maintains a number of solutions (particles);
- each particle has a position and a speed;
- each particle knows about it's own best and the swarm-best position;
- variants can deal boundary conditions.