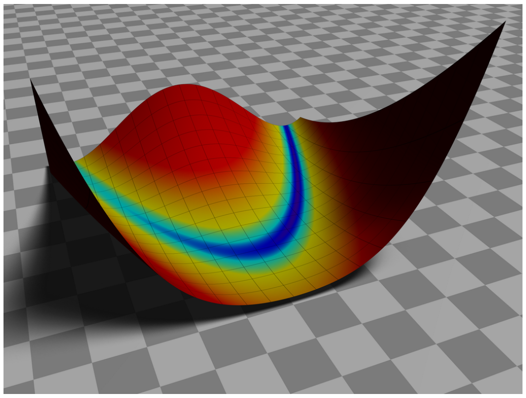
Binary-Coded Genetic Algorithm

Lecture 23



ME EN 575
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Outline

Overview

Genetic algorithms (GAs) are based on three main concepts:

- selection (survival of the fittest)
- reproduction
- mutation (variation)

GAs are part of a larger class of algorithms called evolutionary algorithms.

Initialize Population

Repeat:

1. Compute Fitness
2. Identify Best Member(s) and Check Convergence
3. Selection: Survival of the Fittest
4. Reproduction: Generate Offspring
5. Mutation

Repeat until convergence criteria (e.g., best member stops changing)

Important differences from our past algorithms:

- Probabilistic. Will get different results each time. May need to run multiple times.
- Population-based rather than point-based. Suited for multiobjective optimization, and exploration.
- Real or binary encoding. Can handle discrete variables.
- Easily parallelizable.
- Heuristic, with many variations.

Binary-Coded GA

Consider the following simple example*.

Minimize the cost of a can:

$$
\begin{aligned}
\text{minimize} \quad & \frac{\pi d^2}{2} + \pi d h \\
\text{subject to} \quad & \frac{\pi d^2 h}{4} \geq 300 \text{ ml} \\
& d_{min} \leq d \leq d_{max} \\
& h_{min} \leq h \leq h_{max}
\end{aligned}
$$

* Multi-objective Optimization Using Evolutionary Algorithms, Kalyanmoy Deb

What is a binary number?

Convert the following numbers to binary: $d = 8$, $h = 10$

Combine into one "chromosome":

$$d = 01000, h = 01010$$

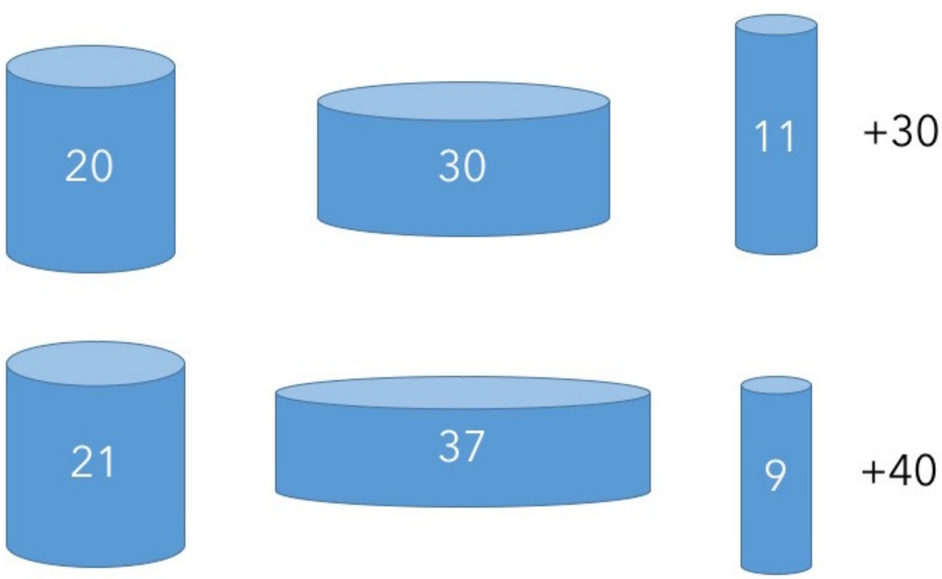
$$x = 0100001010$$

If we flip the first bit, what does that mean for the physical problem?

Initialize Population and Evaluate Fitness

Create a random initial population. As a rule of thumb, the population size should be *at least* 10 times the number of design variables.

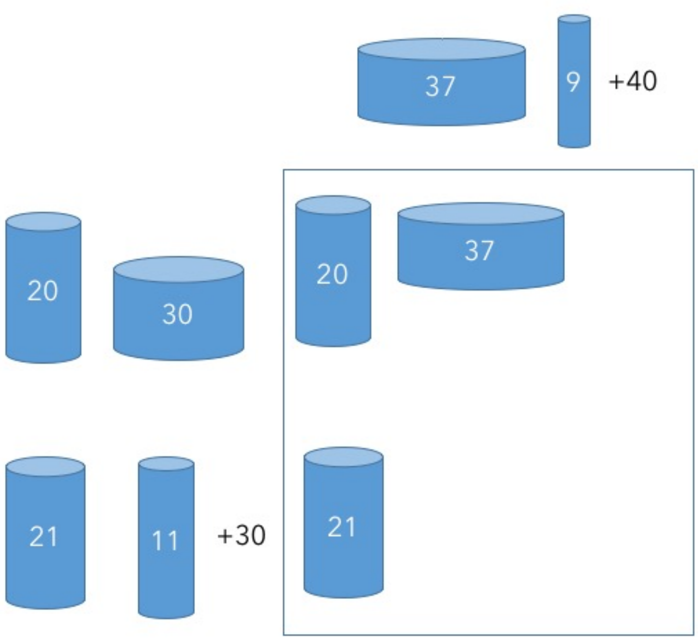
* A good way to do this is with Latin Hypercube Sampling (will take about this later in the semester in connection with Surrogate-Based Optimization).

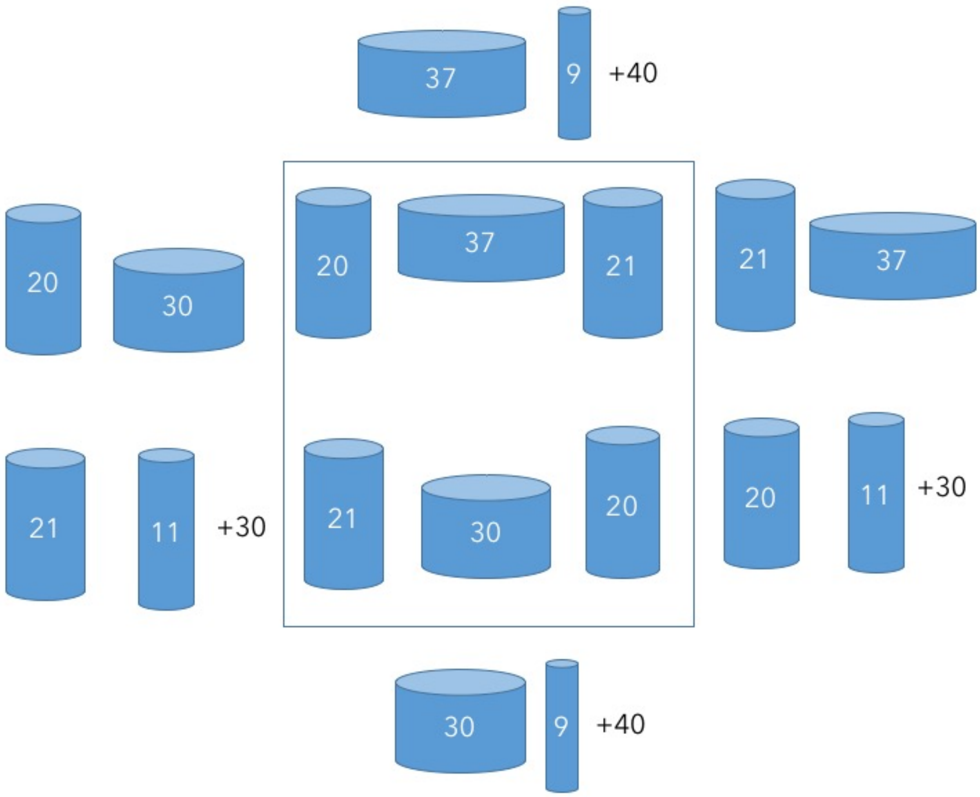


Selection: Survival of the Fittest

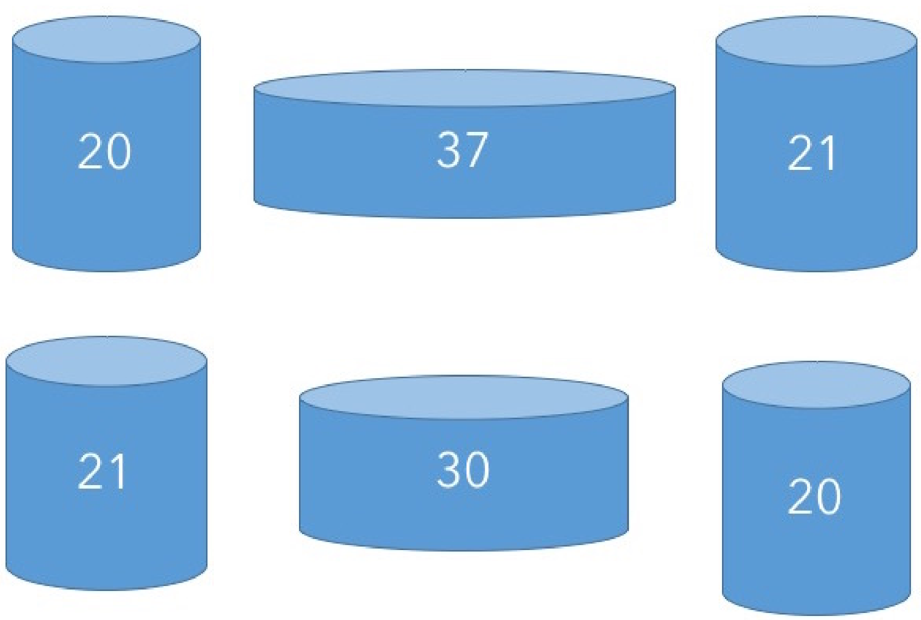
Tournament:

Randomly select pairs. Repeat. Thus, each design will be copied into the new population zero, one, or two times.



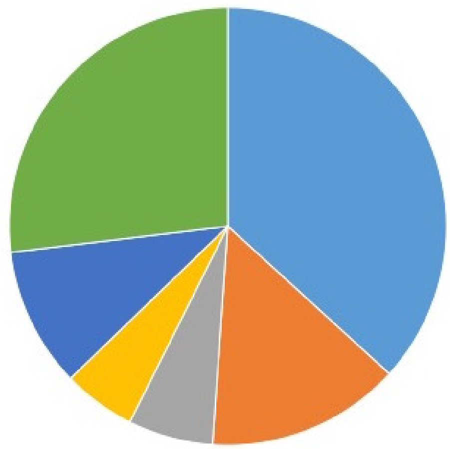


New population:



Roulette Wheel:

Probability of selection is proportional to fitness. In other words, better designs are more likely to survive to the next generation.



Reproduction

Single-point crossover:

Randomly select pairs then random crossover.

Parents:

0 1 0 | 0 0 0 1 0 1 0
0 1 1 | 1 0 0 0 1 1 0

Offspring:

0 1 0 | 1 0 0 0 1 1 0
0 1 1 | 0 0 0 1 0 1 0

Two-point crossover, n-point crossover, and other methods exist as well.

Mutation

Visit each bit, flip with some small probability (e.g., $p < 0.02$)

Variations: visit only random bits.