METAHEURISTICS

Section 3.3
Common Concepts for Evolutionary Algorithms

Common Concepts for EA

- Representation
- Population initialization
- Objective function
- Selection strategy
- Reproduction strategy
- Replacement strategy
- Stopping criteria

Selection Methods

- Proportional fitness assignment
  - The absolute fitnesses are associated with individuals
- Rank-based fitness assignment
  - The relative fitnesses are associated with individuals

- Roulette wheel selection
- Stochastic universal sampling
- Tournament selection
- Rank-based selection

Roulette Wheel Selection and Stochastic Universal Sampling

Individuals:	1	2	3	4	5	6	7
Fitness:	1	1	1	1.5	1.5	3	3

$$p_i = f_i \Big/ \left(\sum_{j=1}^{n} f_j\right)$$

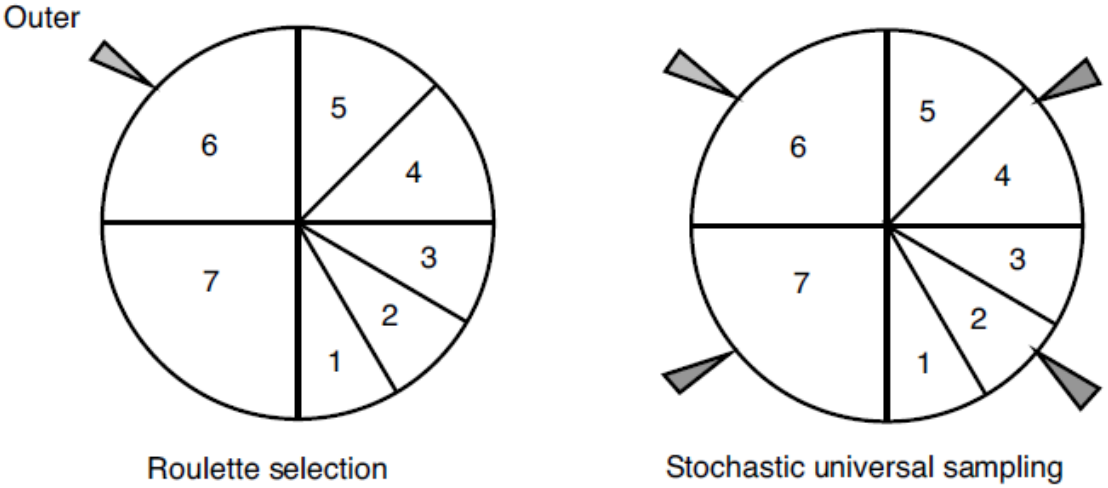


FIGURE 3.11 Roulette selection strategies. In the standard roulette selection, each spin selects a single individual. In SUS, a spin will select as individuals as outers (e.g., four individuals in the example).

Tournament Selection

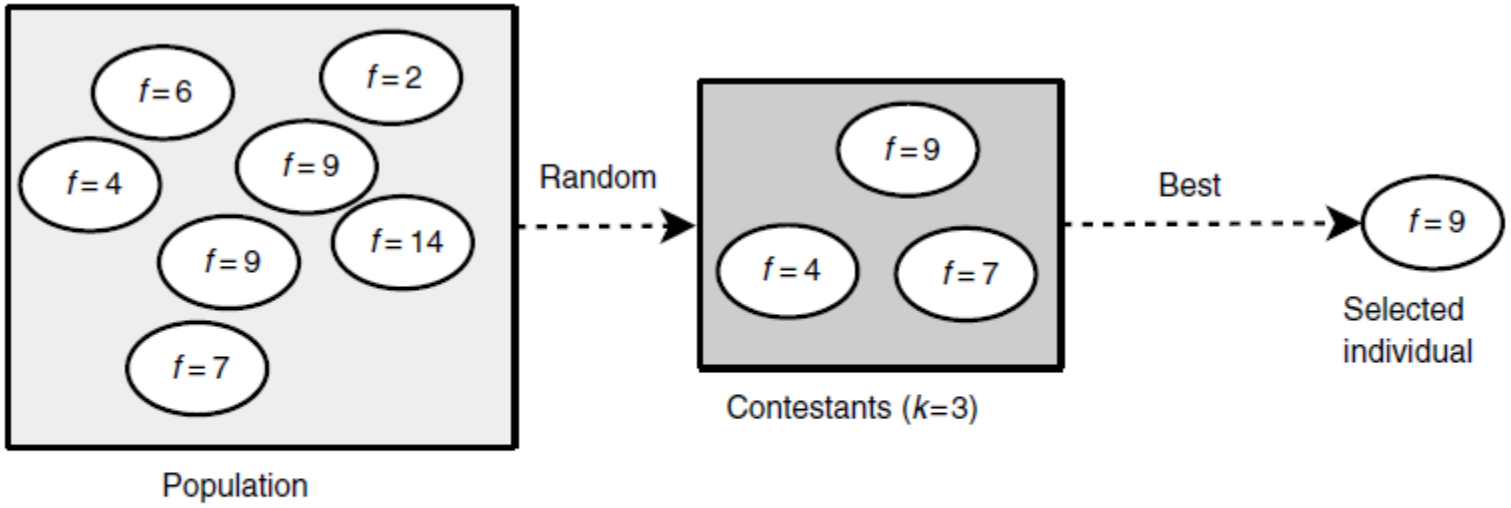
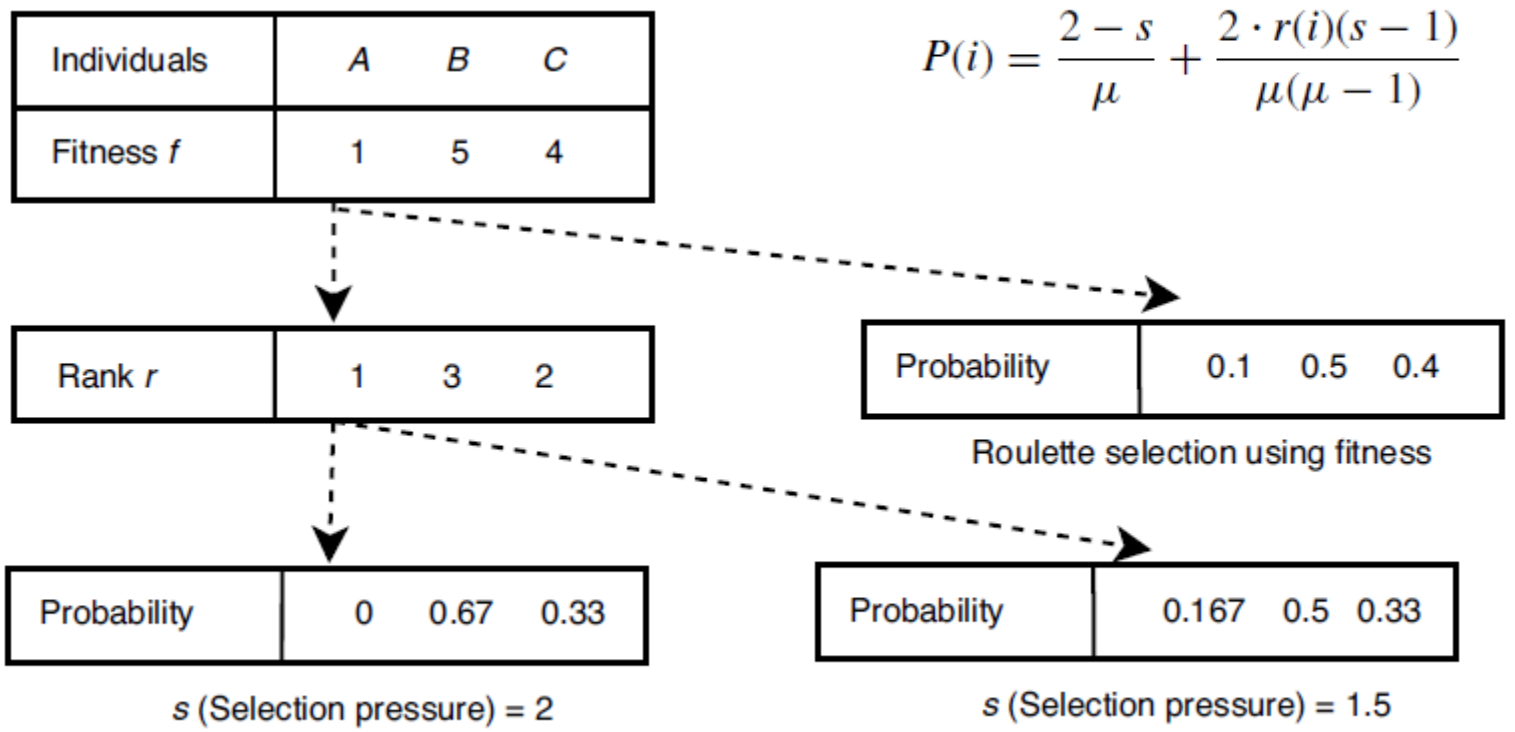


FIGURE 3.12 Tournament selection strategy. For instance, a tournament of size 3 is performed. Three solutions are picked randomly from the population. The best solution from the picked individuals is then selected.

Rank-Based Selection



$$P(i) = \frac{2-s}{\mu} + \frac{2 \cdot r(i)(s-1)}{\mu(\mu-1)}$$

FIGURE 3.13 Rank-based selection strategy using a linear ranking.

Reproduction

- Mutation
- Recombination or crossover

Mutation

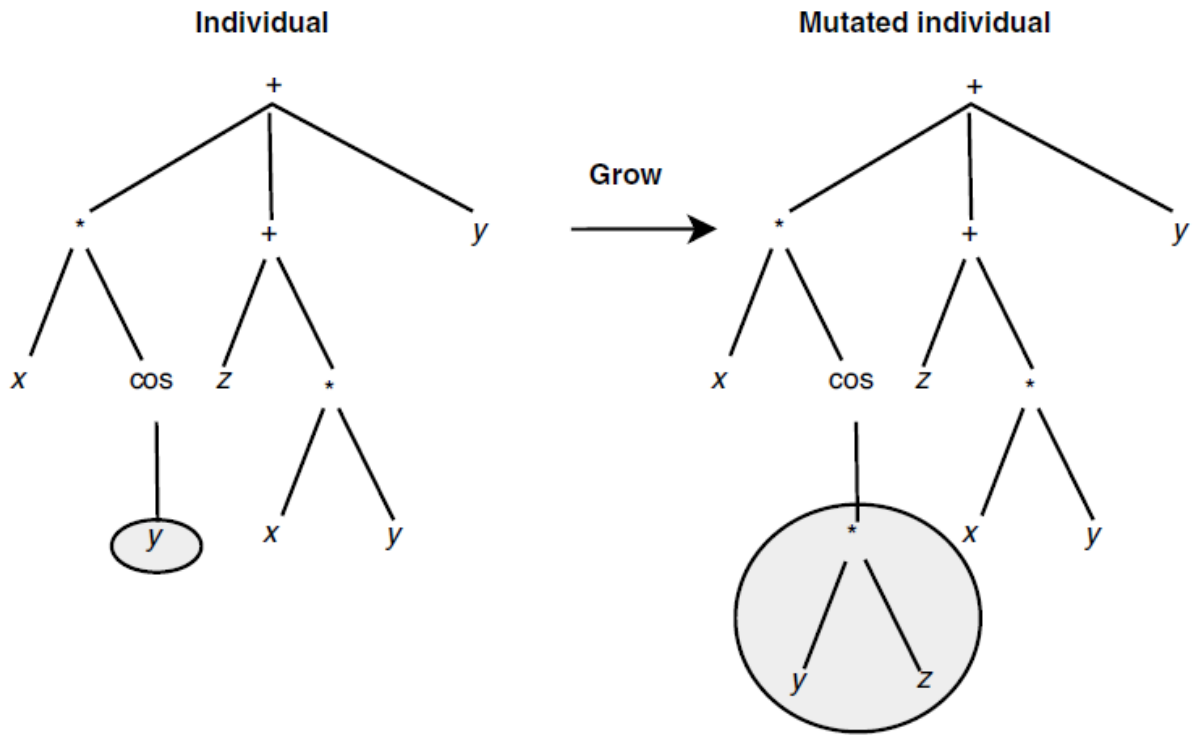
- Ergodicity
  - The mutation operator should allow every solution of the search space to be reached
- Validity
  - The mutation operator should produce valid solutions
- Locality
  - The mutation should produce a minimal change.

Mutation Operators

- Mutation in binary representation
  - Flip operator
- Mutation in discrete representation
  - Change the value associated with an element by another value of the alphabet
- Mutation in permutations
  - Swapping
  - Inversion
  - Insertion

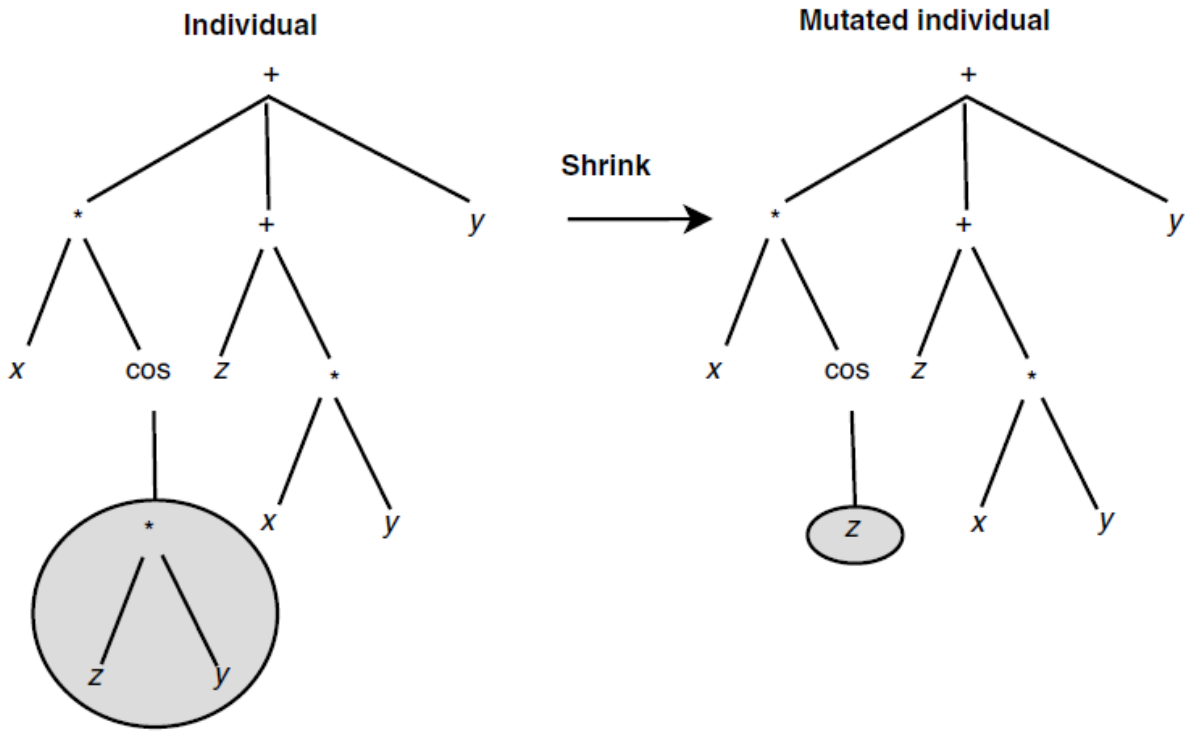
Grow Mutations

- A terminal node is selected randomly and replaced by a randomly generated subtree



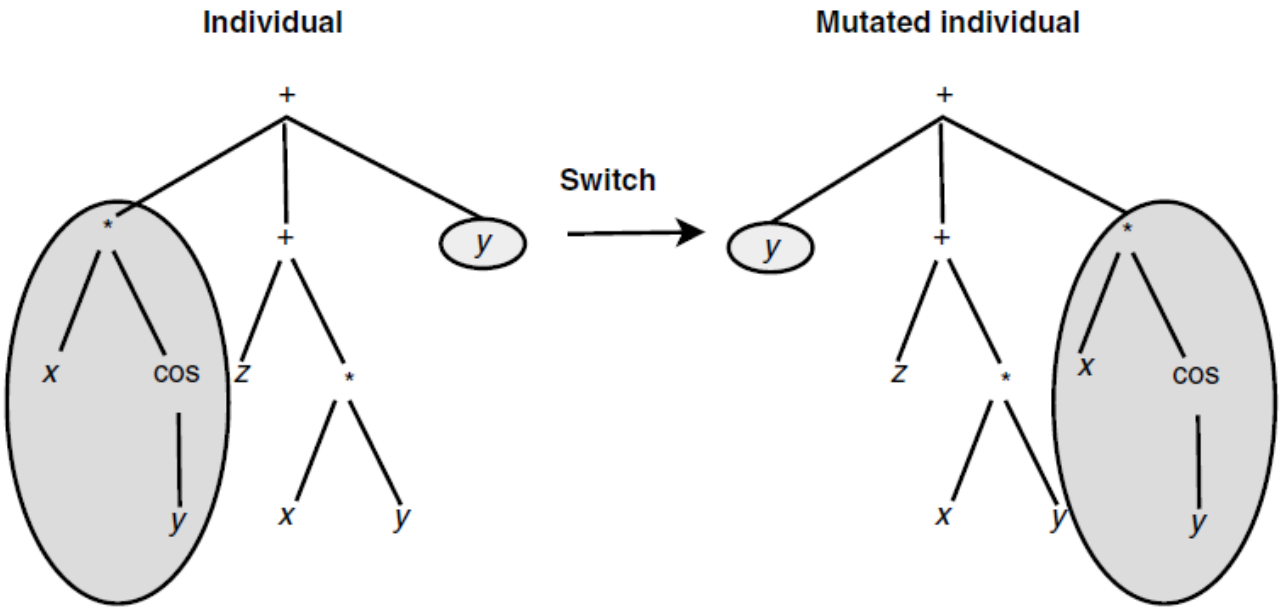
Shrink Mutations

- An internal node is selected randomly and replaced by a randomly generated terminal



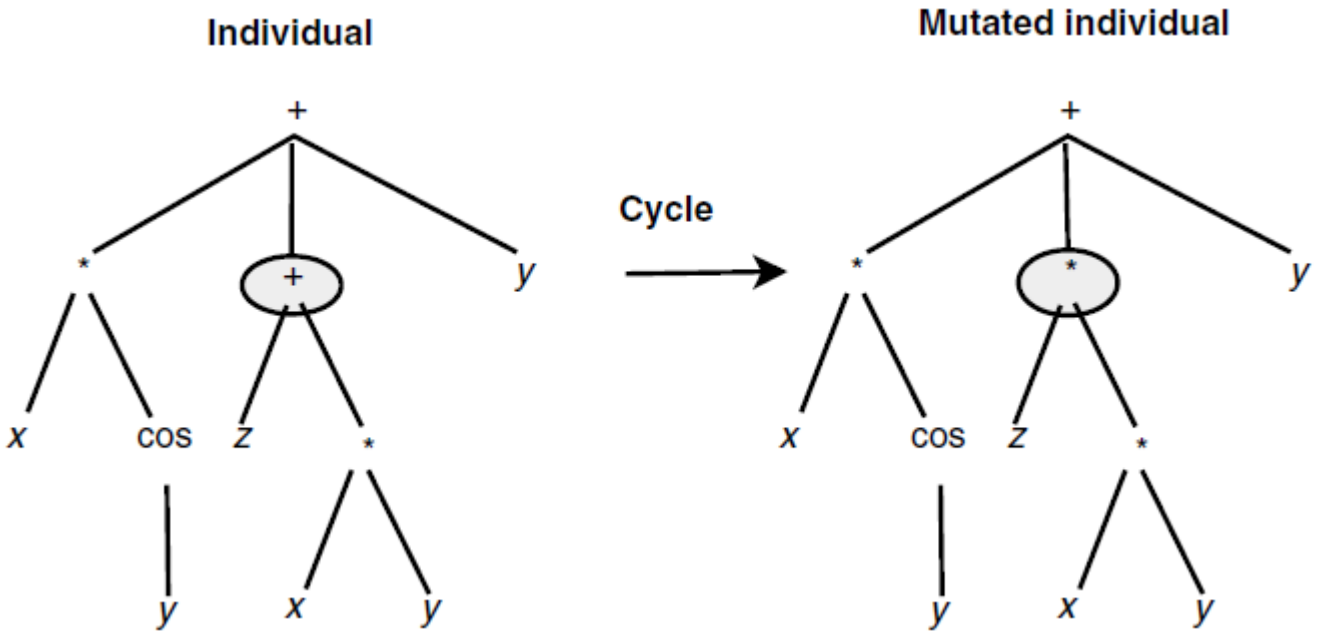
Switch Mutations

- An internal node is selected randomly, two of its subtrees are selected randomly and their positions in the tree are switched



Cycle Mutations

- A single node (internal or terminal) is selected randomly and replaced by a random node with the same number of arguments



Mutation Operators

$$x' = x + M$$

- Uniform random mutation
  - $x' = x + U(-b, b)^n$

- Normally distributed mutation
  - $x' = x + N(0, \sigma)$

Mutation Operators

- Polynomial mutation

$$x_i' = x_i + \left(x_i^u - x_i^L\right)\delta_i$$

$$P(\delta) = 0.5(\eta_m + 1)(1 - |\delta|^{\eta m})$$

$$\delta_i = \begin{cases} (2r_i)^{\frac{1}{\eta_m+1}} - 1 & \text{if } r_i < 0.5 \\ 1 - (2(1 - r_i))^{\frac{1}{\eta_m+1}} & \text{otherwise} \end{cases}$$

Recombination or Crossover

- Heritability
  - Respectful
  - Assorting
- Validity

- 1-point crossover
- N-point crossover
- Uniform crossover

Crossover Operators

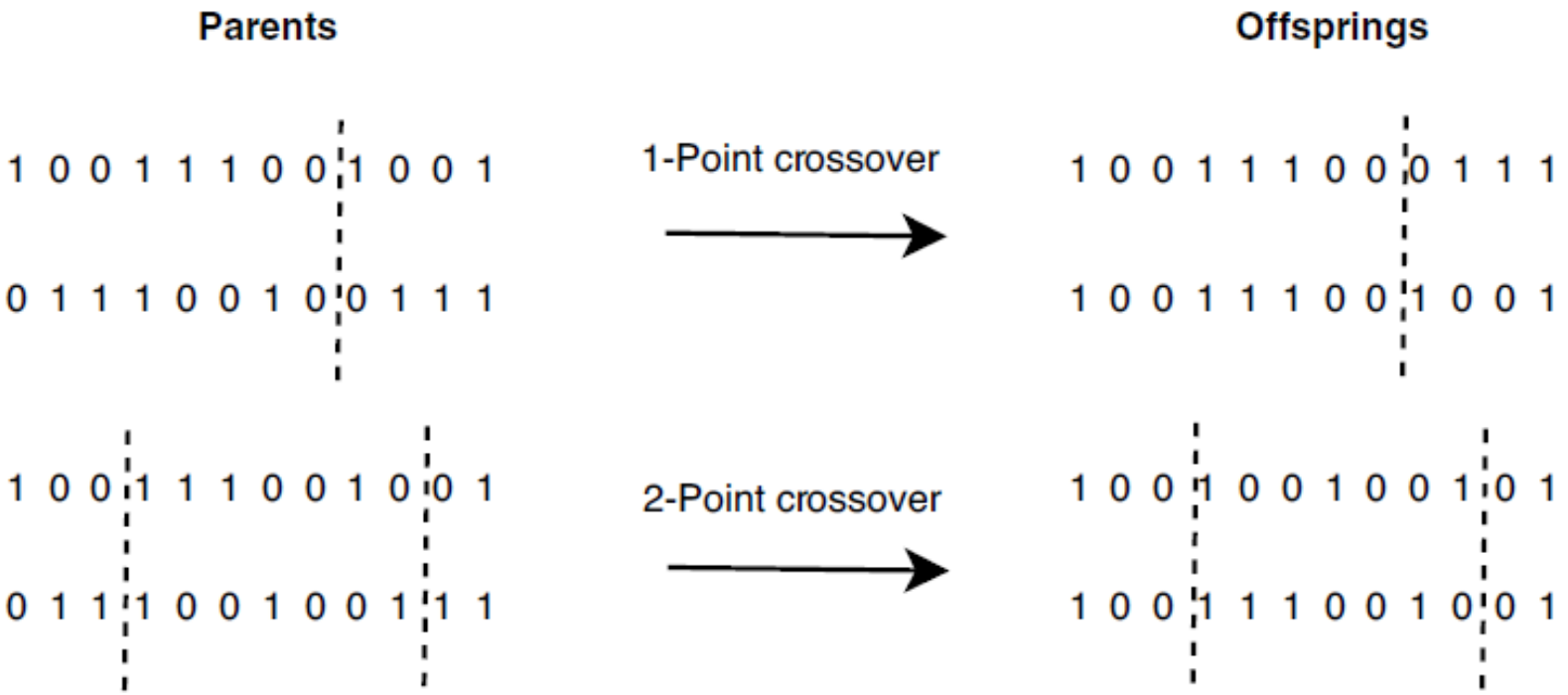


FIGURE 3.16 1-point and *n*-point crossover operators.

Crossover Operators

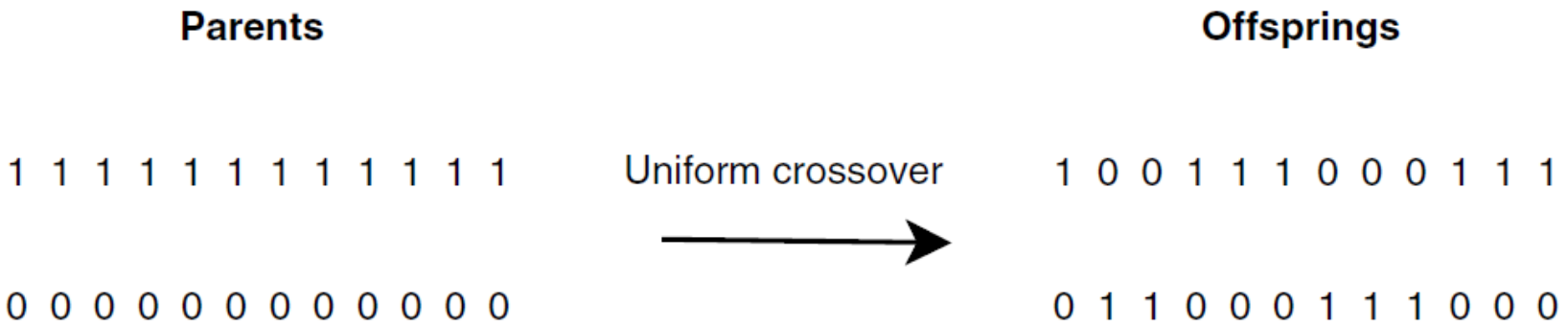


FIGURE 3.17 The uniform crossover operator.

Mean-Centric Recombination

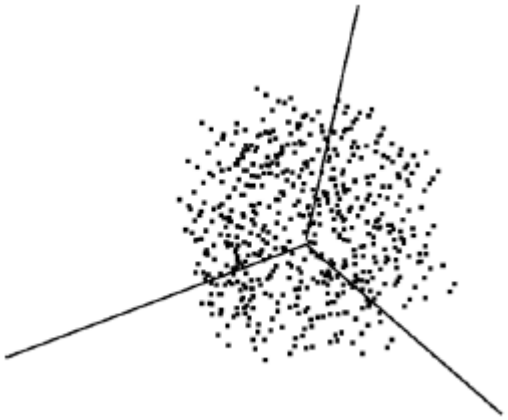
- Intermediate crossover

$$o_i = \alpha x_{1i} + (1 - \alpha) x_{2i}$$

- Geometrical crossover

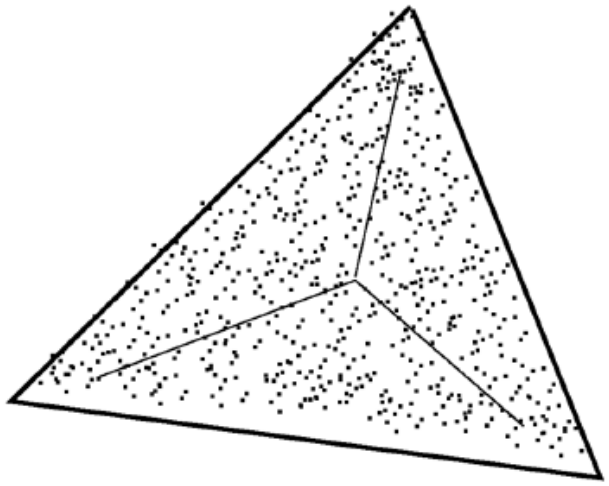
$$o_i = ((x_{11}x_{21})^{0.5}, \ldots, (x_{1n}x_{2n})^{0.5})$$

- Unimodal normal distribution crossover



Mean-Centric Recombination

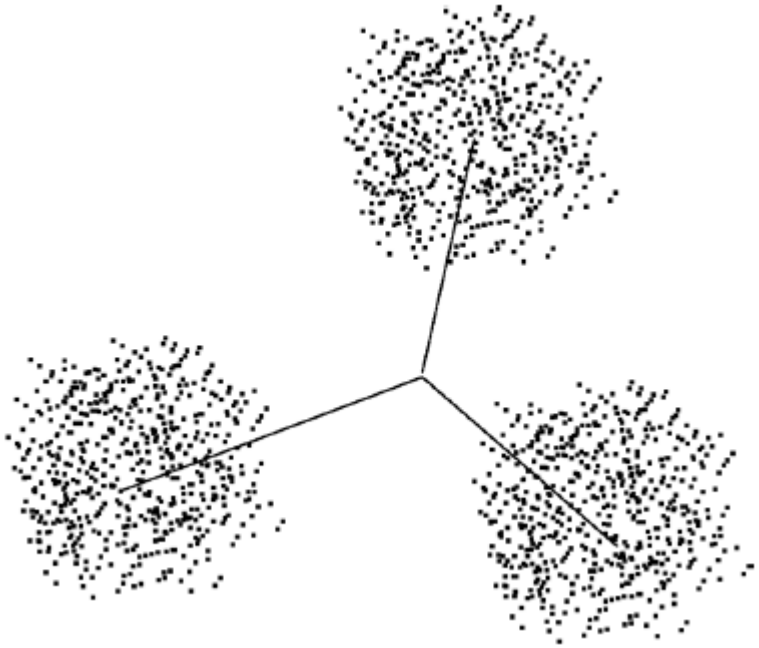
- Simplex crossover (SPX)



Parent-Centric Recombination

- Simulated binary crossover (SBX)

- Parent-centric crossover (PCX)



Permutation crossover operators

- Order crossover (OX)

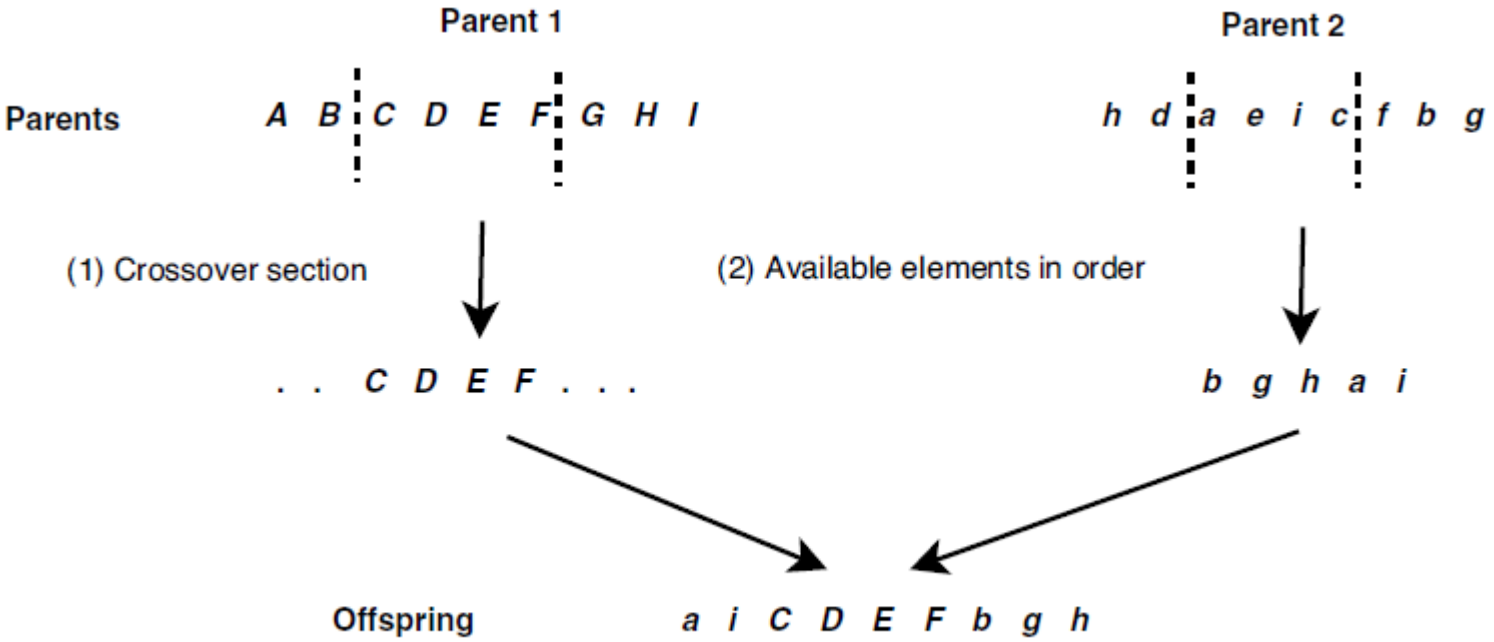


FIGURE 3.19 The order crossover for permutations.

Permutation crossover operators

- Partially mapped crossover (PMX)

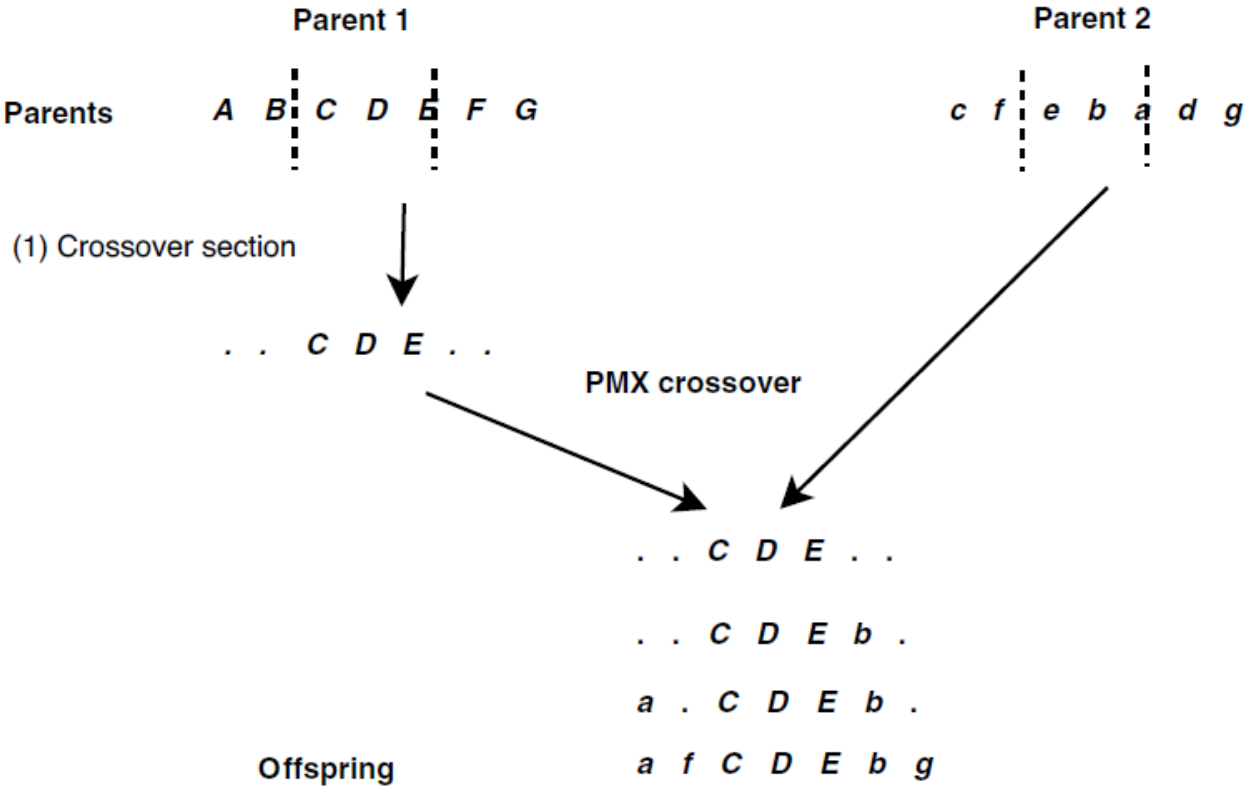


FIGURE 3.20 The partially mapped crossover for permutations.

Permutation crossover operators

- Two-point crossover

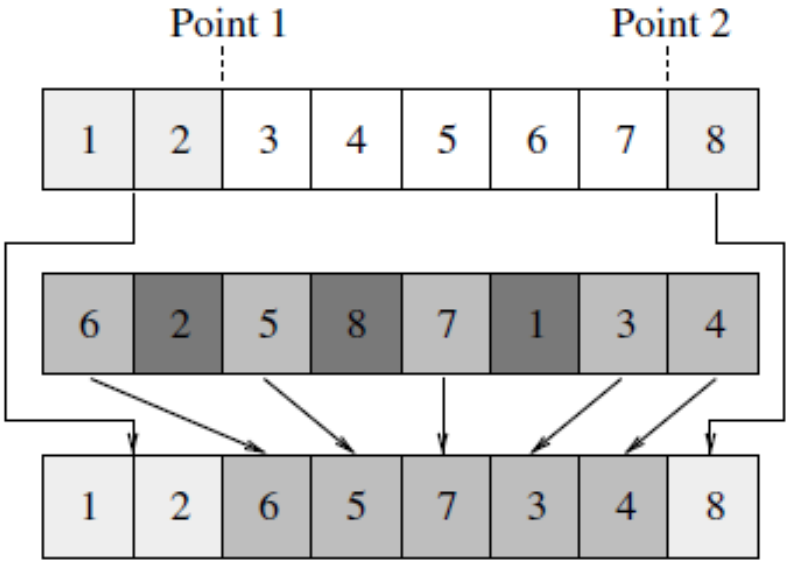


FIGURE 3.21 Two-Point crossover operator for permutations.

Tree crossover operators

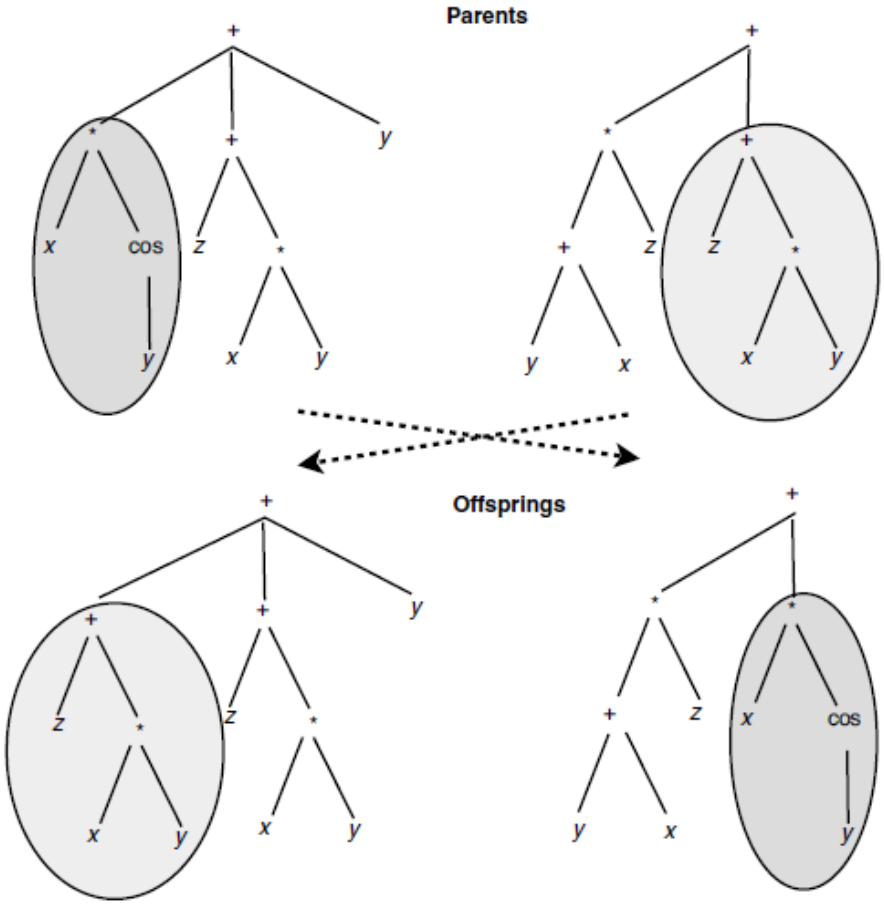


FIGURE 3.22 A crossover operator for parse tree representations.

Replacement Strategies

- Generational replacement
- Steady-state replacement

Common Parameters of EA

- Mutation probability $\in [0.001, 0.01]$
- Crossover probability $\in [0.3, 0.9]$
- Population size $\in [20, 100]$