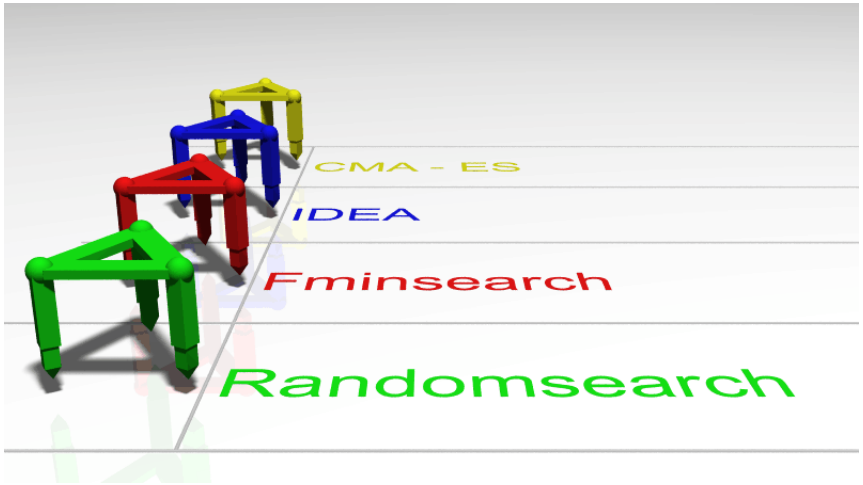

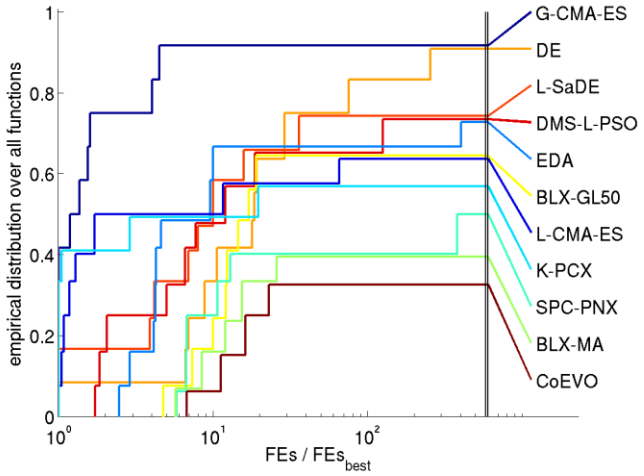

Evolutionary Computation

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ENGG7302: Advanced Computational Techniques in Engineering

References

- C. Blum and A. Roli. **Metaheuristics in Combinatorial Optimization: Overview and Conceptual Comparison**. *ACM Computing Surveys, Vol.35, No.3, Sept. 2003, pp. 268-308.*
- Sean Luke, 2009, ***Essentials of Metaheuristics***, *available at:* http://cs.gmu.edu/!sean/book/metaheuristics/

Outline

- Definitions
- Standard EC Algorithms
  - Genetic Algorithm
  - Evolution Strategies
  - Genetic Programming
- Example Applications
  - Function Optimisation
  - Engineering Design

Optimisation (recap)

- Have access to an objective (fitness) function.
- Combinatorial: Choose a combination of variables.
- Continuous function: Select values for a set of variables.
- Limited number of evaluations.
- How do we incorporate prior knowledge of evaluated solutions into future solution decisions?

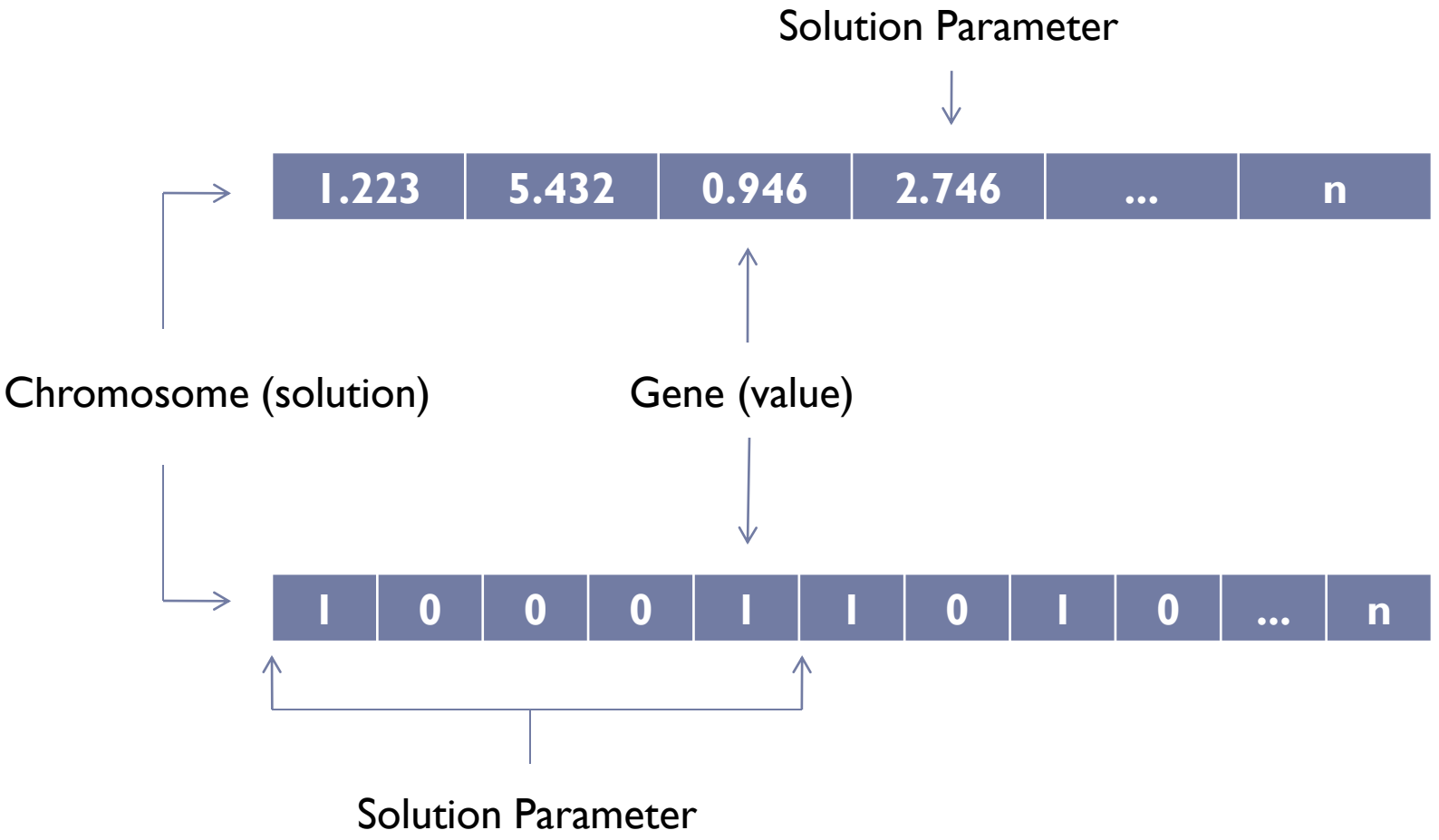
Evolution

- Natural selection: death of the weakest / survival of the fittest.
- Genetic drift: effect of random chance on the propagation of a particular trait.
- Two processes allow differences between generations:
  - Recombination
  - Mutation
- Slow process.

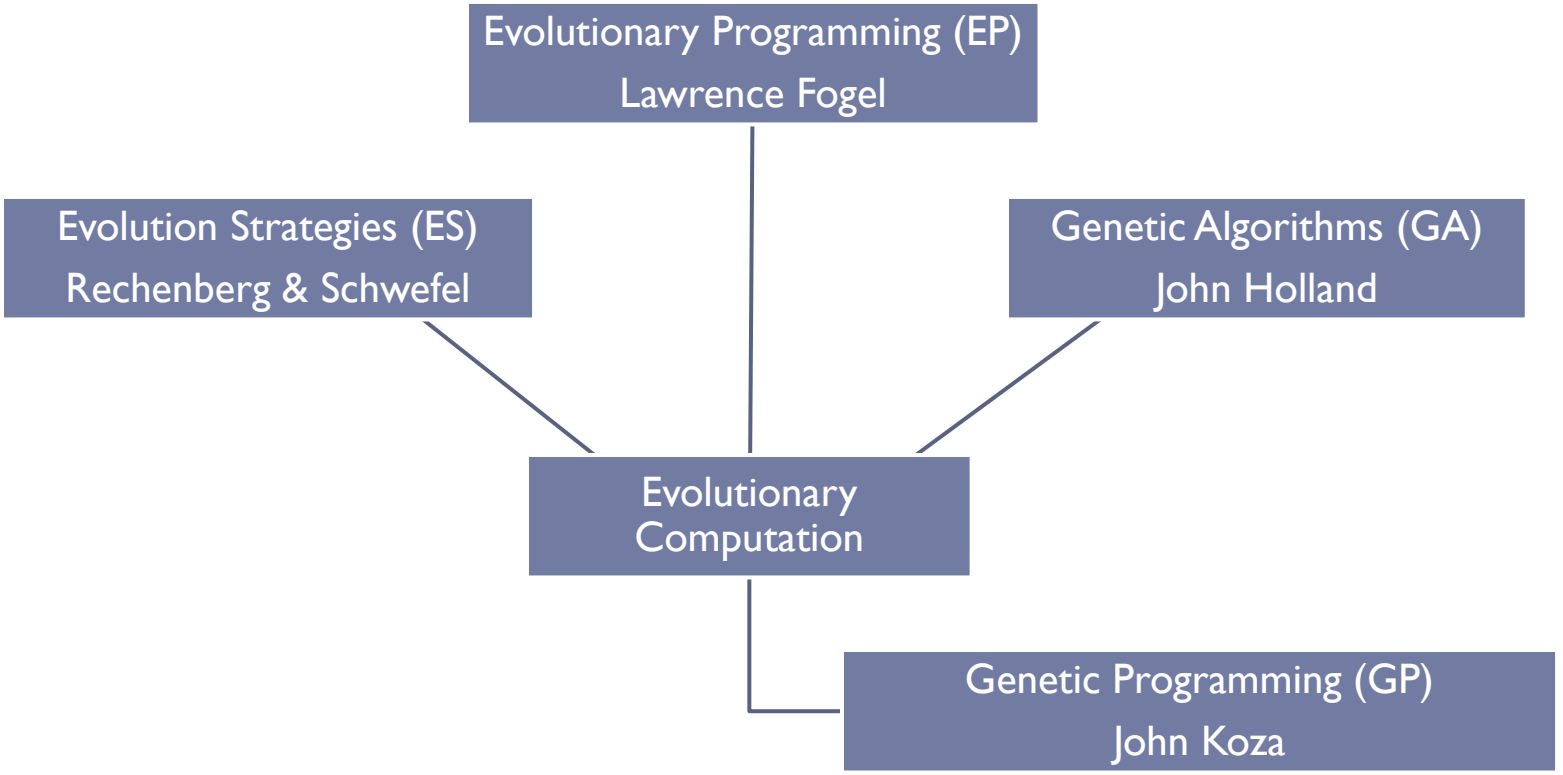
Evolutionary Computation

- Computer algorithms that use principles of evolution to build solutions to optimisation problems.
  - Selection
  - Recombination
  - Mutation
  - Replacement
- Population based algorithms.

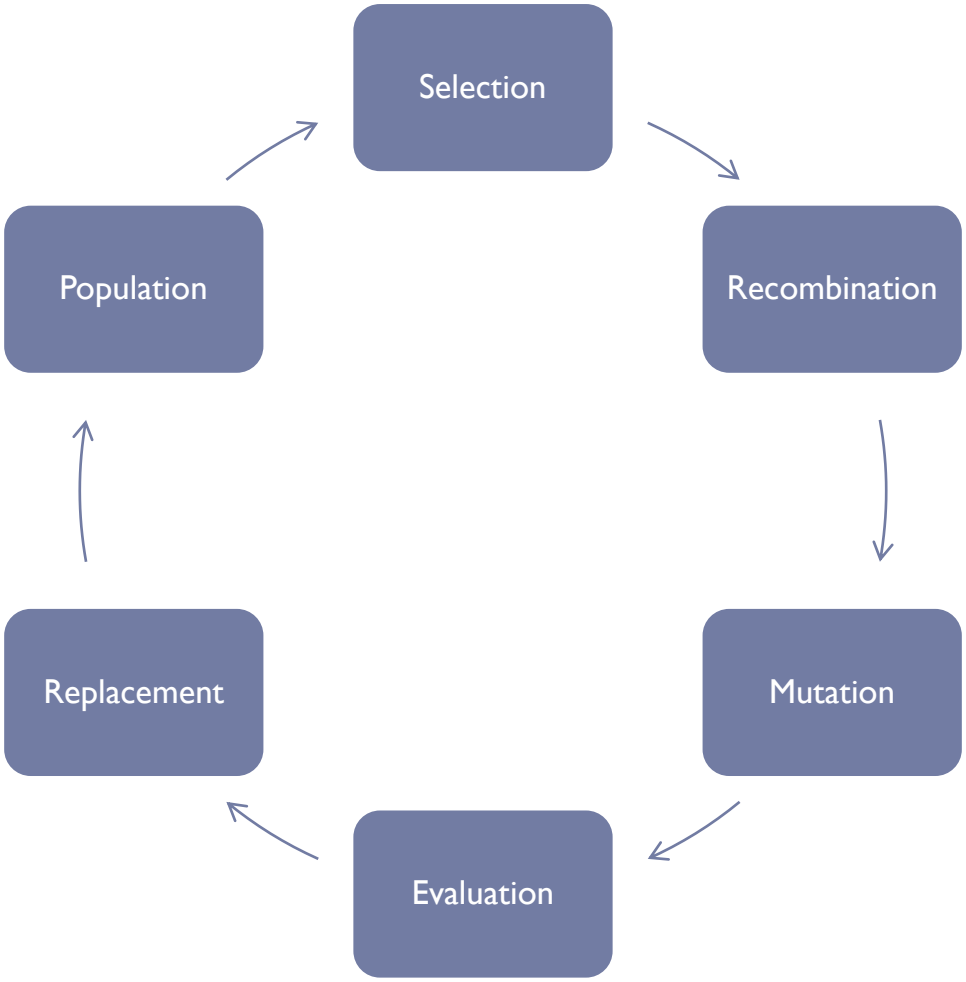
Definitions (Real Value vs Binary Encoding)



History of Evolutionary Computation



General Algorithm Design

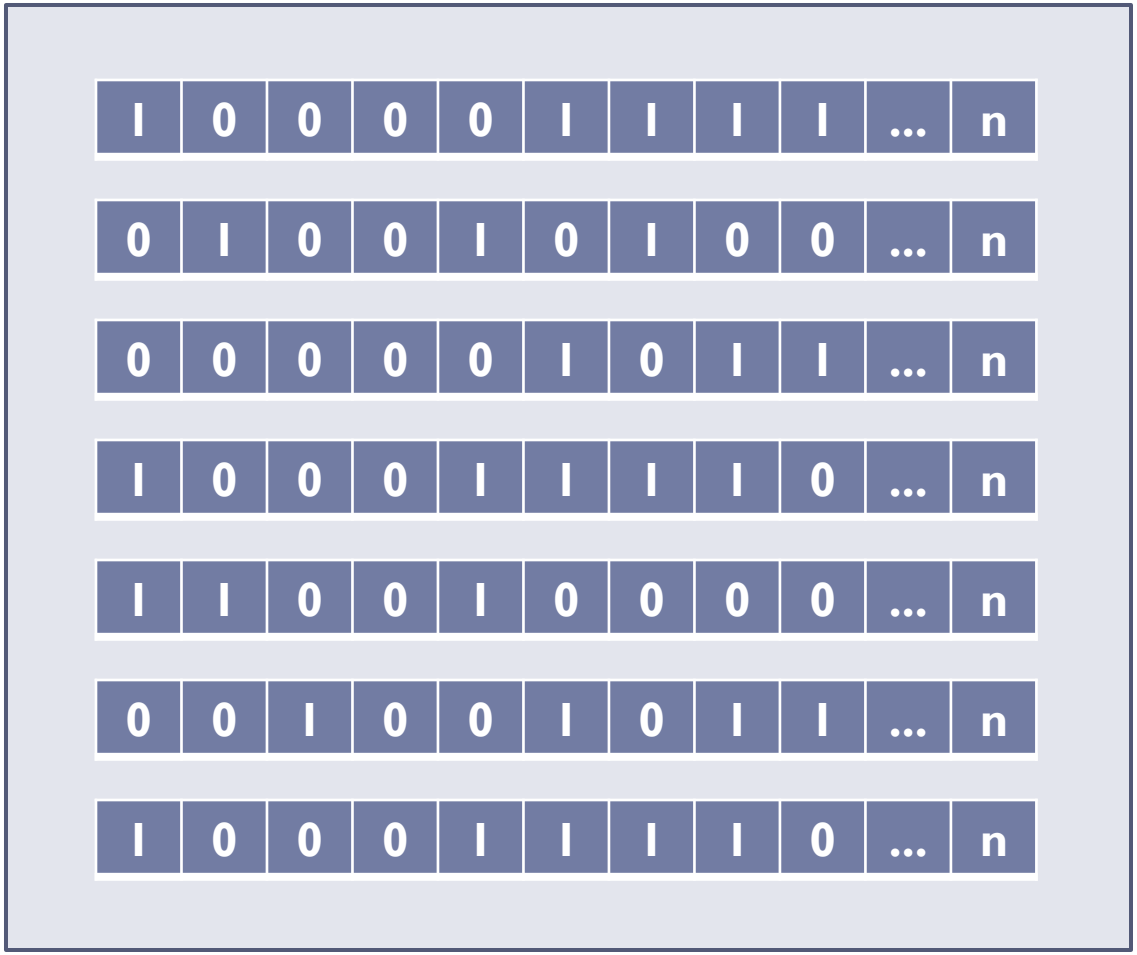


Genetic Algorithm

- Binary coded solutions (although real values are used in some circumstances).
- Selection: Tournament, roulette wheel, random.
- Recombination: Crossover (1 point, ... , n point)
- Mutation: bit flip, bit exchange, real value Gaussian mutation.
- Replacement: Generational, steady-state, crowding.

Binary Encoded Population

Population

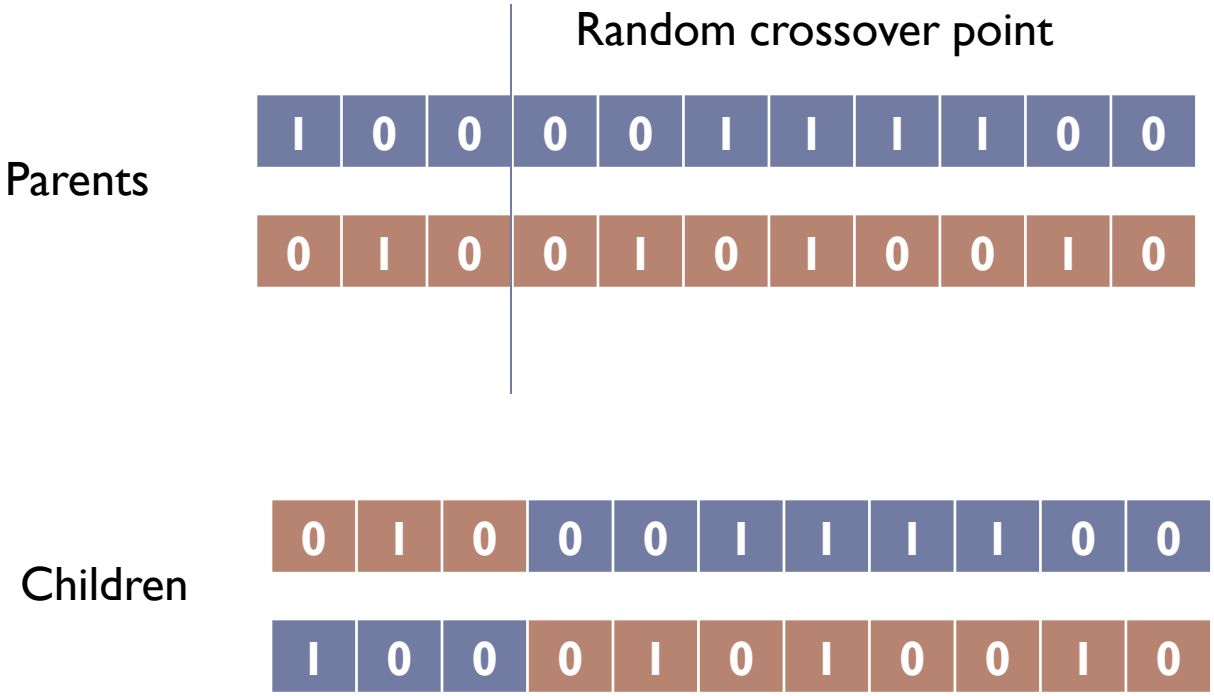


Random initialisation (can be biased random if you have reason to think that it may help)

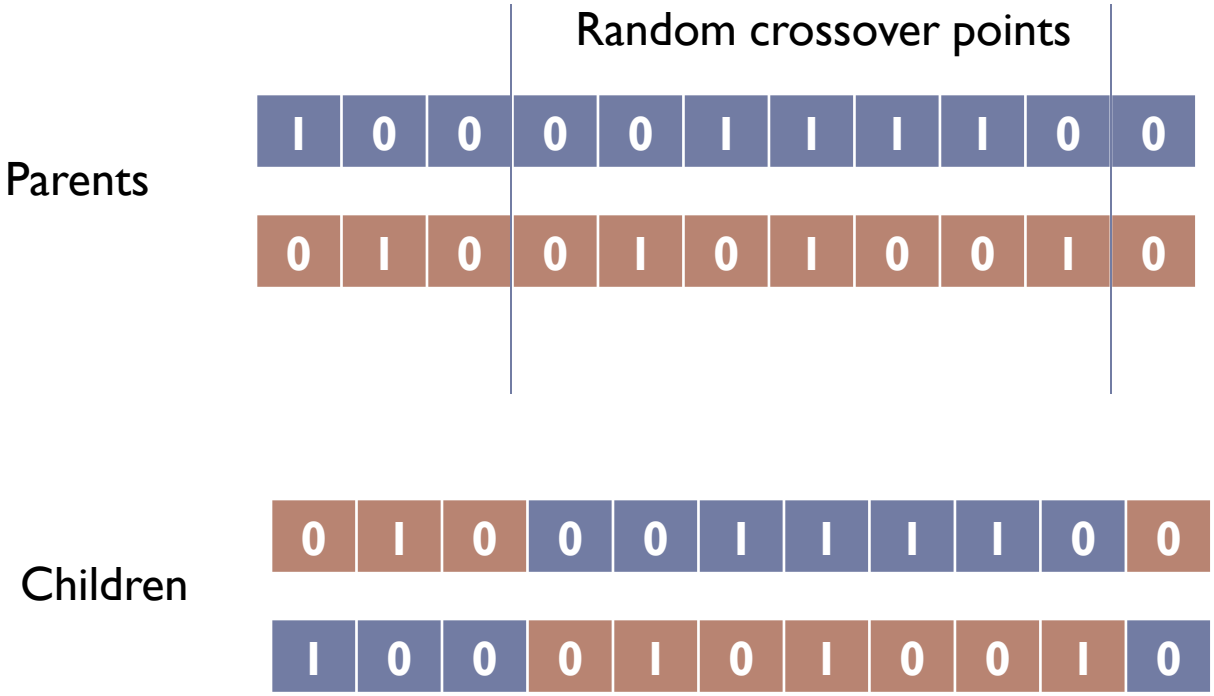
Selection

- Roulette wheel
- Tournament
- Random

Recombination (1 point crossover)

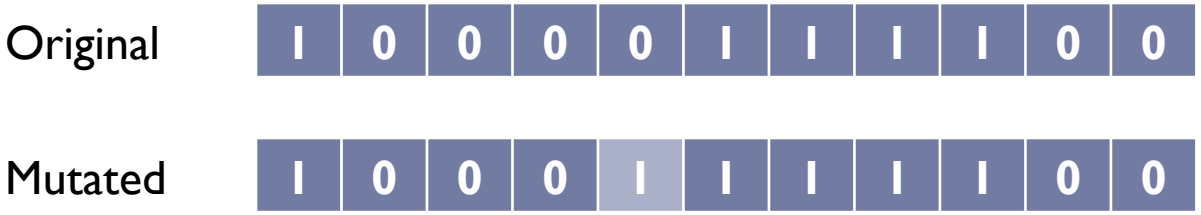


Recombination (2 point crossover)

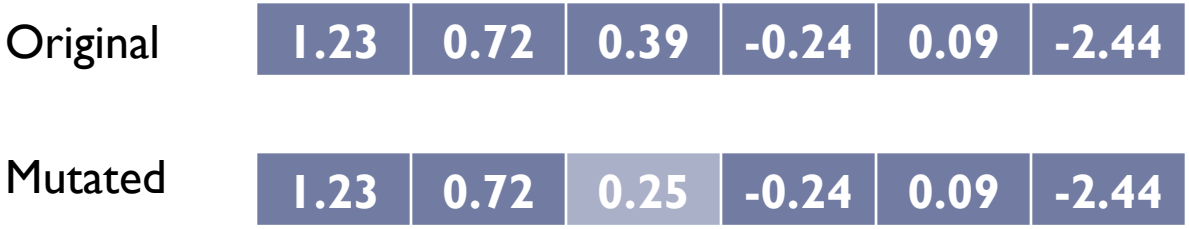


Mutation

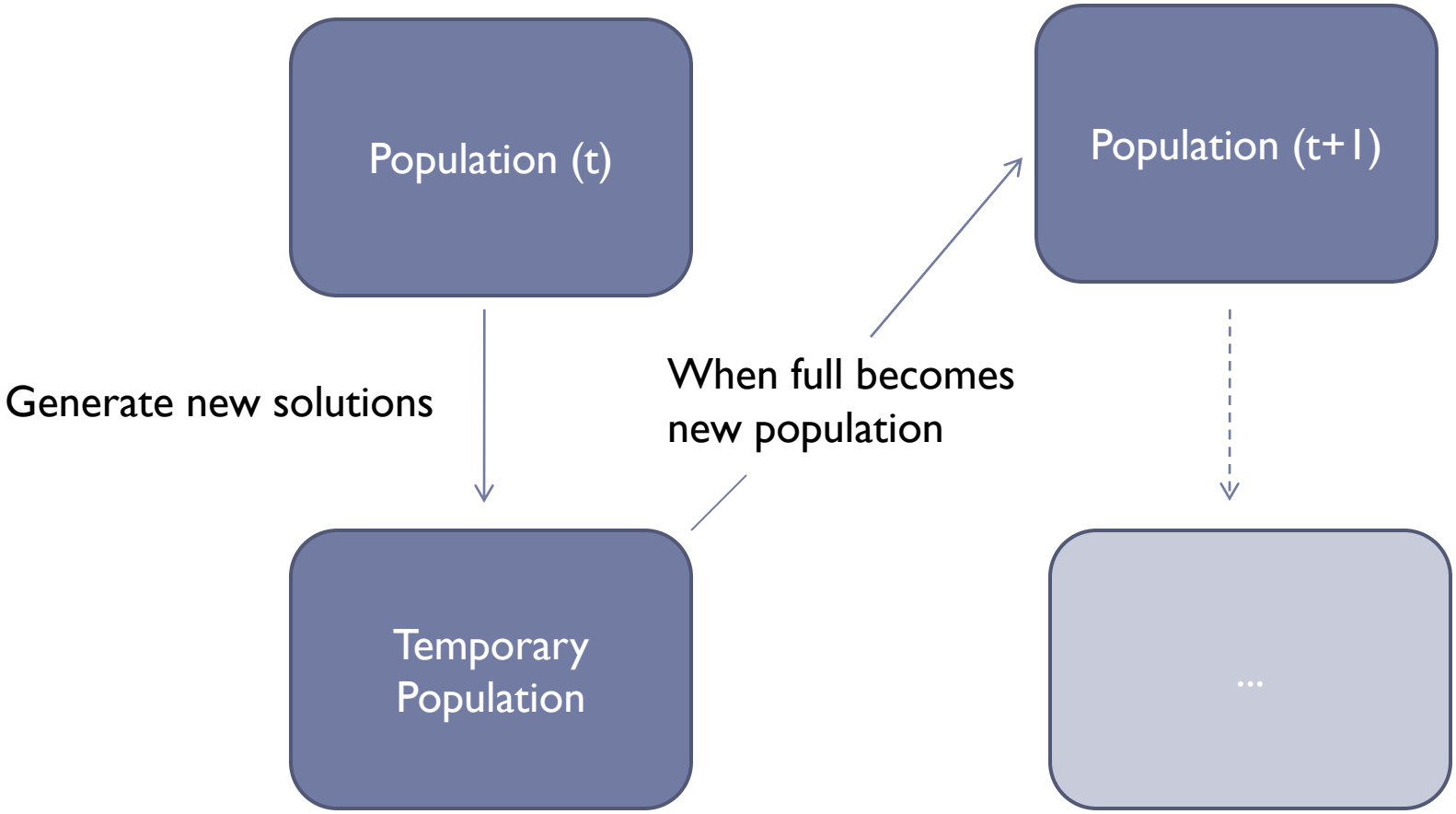
- Bit flip



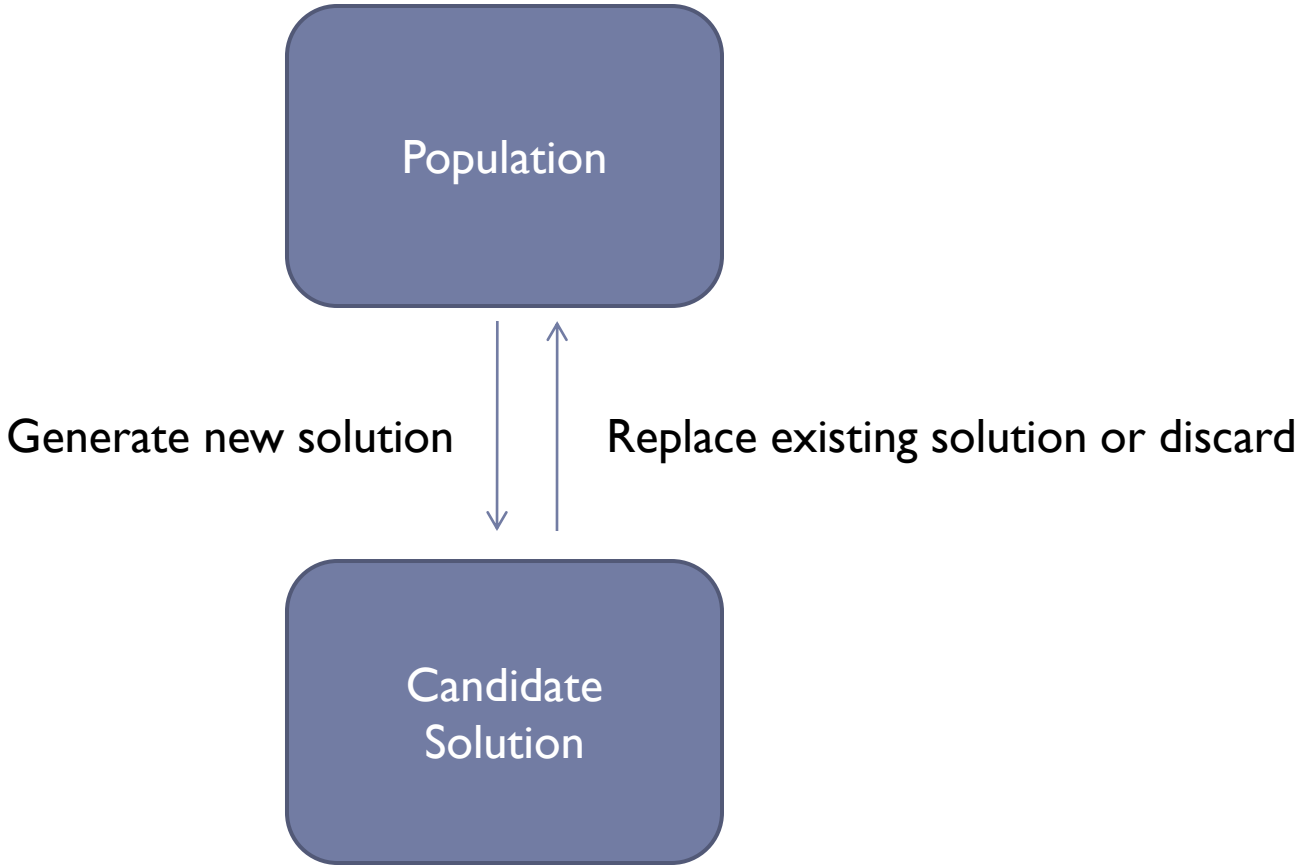
- Real value



Replacement (Generational)



Replacement (Steady-state)



Evolution Strategies

- Real value coded solutions.
- Two canonical versions:
  - $(\mu / \rho, \lambda)$-ES
  - $(\mu / \rho+\lambda)$-ES
  - μ: number of parents.
  - ρ: mixing number, number of parents involved in the creation of a new offspring (less than or equal to μ).
  - λ: number of offspring.

Genetic Programming

- Won't go into too much detail here.
- Higher order EC algorithm (not bits or real values, but large solution components)
- Solutions are composed of subroutines or commands.
- Recombined, mutated to evolve a command list.
- Useful for:
  - Robot controllers: evolve behaviours for wall following, robosoccer playing, etc.
  - Electronics: circuit synthesis problems.

Intensification versus diversification

- How do EC algorithms control intensification and diversification?
- Selection
  - Fittest - - - - Random
- Reproduction
  - Large - - - - None
- Mutation
  - Lots - - - - None
- Replacement
  - Greedy - - - - non-Greedy

Summary

- Evolutionary Computation algorithms are useful in finding **approximate** solutions to complex problems.
- Have been used successfully in many practical contexts:
  - Finance: Portfolio selection.
  - Engineering: Many patent infringements and novel solutions through application of EC, design of test cases, approximate solutions to very complex problems.
  - Design: Building design, streetscape matching.
  - Science: Physics model parameter exploration.
  - Art: EC Art is a growing area of interest.