Selection-Replacement Island GA

Sabah Sayed

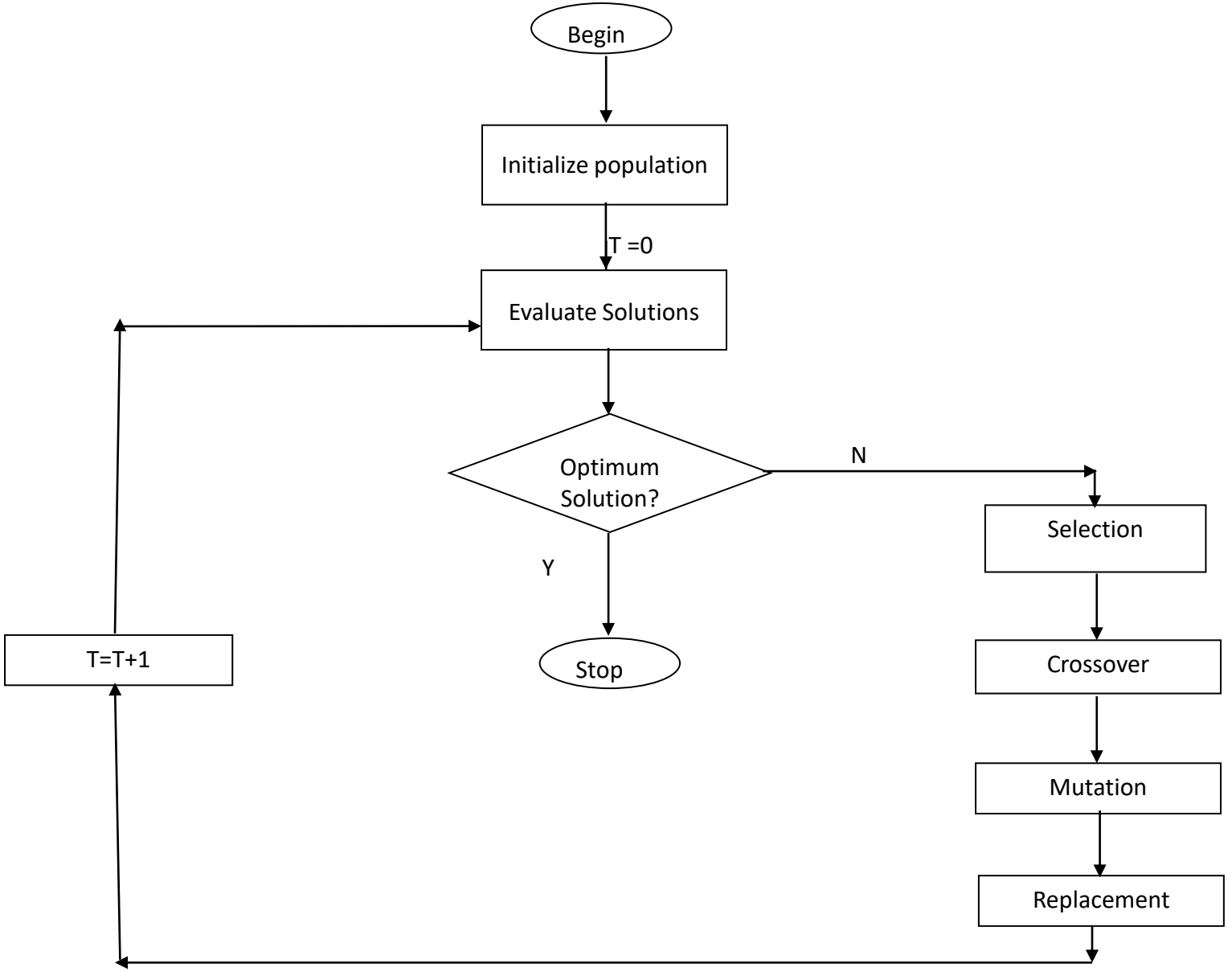
Department of Computer Science

Faculty of Computers and Artificial Intelligence

Cairo University

Egypt

Remember: Mechanism Of GAs



Various Strategies for the Genetic Operators

- Different GAs use different …… strategies.
  - Representation (encoding/decoding)
  - Crossover
  - Mutation
  - Selection
  - Replacement

Selection Operator

- Purpose: to focus the search in promising regions of the space
- Bias the mating pool (those who can pass on their traits to the next generation) with fitter individuals

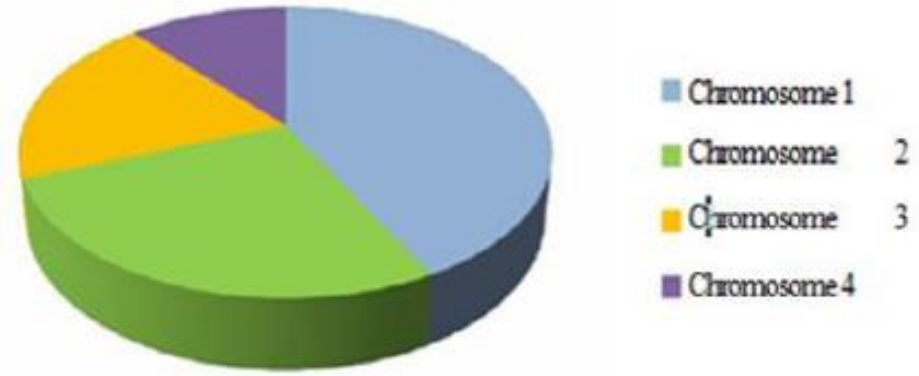
- Selection can occur in two places:
  - Selection from *current generation* to take part in mating (parent selection)
  - Selection from *parents + offspring* to go into next generation (Replacement Strategy)

Fitness Based Competition

- Selection operators work on whole individual
  - i.e. they are representation-independent
- Distinction between selection
  - operators: define selection probabilities
  - algorithms: define how probabilities are implemented
- Chance to be selected as parent proportional to fitness:
  - Roulette wheel selection
  - Rank selection
- To avoid problems with fitness function
  - Tournament selection algorithm

Rank Selection Technique

- Roulette wheel suffers from premature convergence.
- An alternative is **Rank Selection**. Attempt to remove problems of FPS (Fitness Proportional Selection) by basing selection probabilities on ***relative*** rather than ***absolute*** fitness
- Based on sorting of individuals by decreasing fitness



Rank Selection Technique

Steps:

1. Rank selection first ranks the population and then every chromosome receives fitness from this ranking.
2. The worst will have fitness 1, second worst 2 etc. and the best will have fitness N (number of chromosomes in population).
3. Then calculate cumulative Fitness.
4. The next steps is same as roulette wheel.

Rank Selection Technique

Example:

Assuming these are the individual fitnesses: 10, 9, 3, 15, 85, 7.

- Sort the individuals according to fitness 3,7,9,10,15,85
- Assign the ranks in **ascending order**: 1: **3**, 2: **7**, 3: **9**, 4: **10**, 5: **15**, 6: **85**
- Sum of all ranks is 1+2+3+4+5+6 = 21 (or using the **gauss formula** :

  N*(N+1)/2) ➔ (6+1)*6/2 = **21**.
- Compute the probabilities as:

  1/21 , 2/21 , 3/21 , 4/21 , 5/21 , 6/21

  ➔ 0.047, 0.095, 0.143, 0.19, 0.24, 0.29
- Apply roulette wheel on those probabilities.

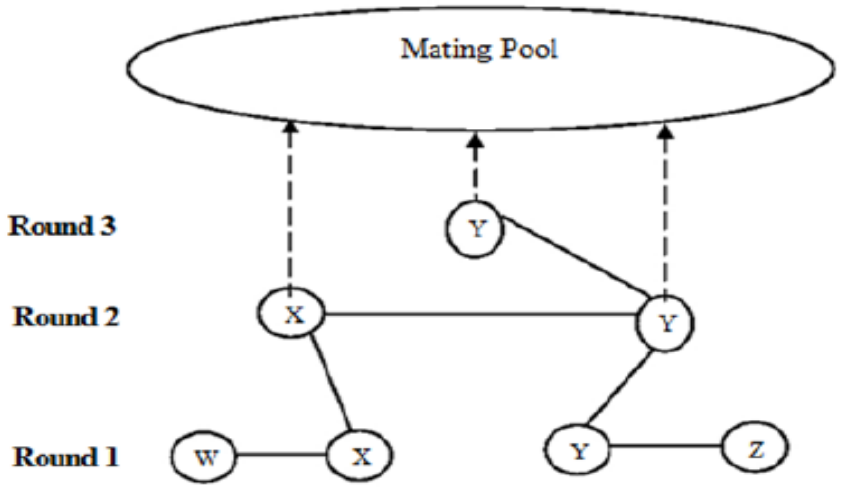
Rank Selection Technique

- What are the problems that could arise?
  - Computationally expensive because it sorts the populations based on fitness value.
- Can lead to slower convergence, because the best chromosomes do not differ so much from other ones.
- It preserves diversity hence leads to a successful search.

Tournament Selection Technique

Algorithm:

- Choose ***n*** individuals randomly
- Pick the one with highest fitness
- Place ***n*** copies of these individual in the mating pool
- Repeat the process till all in the original population have been chosen

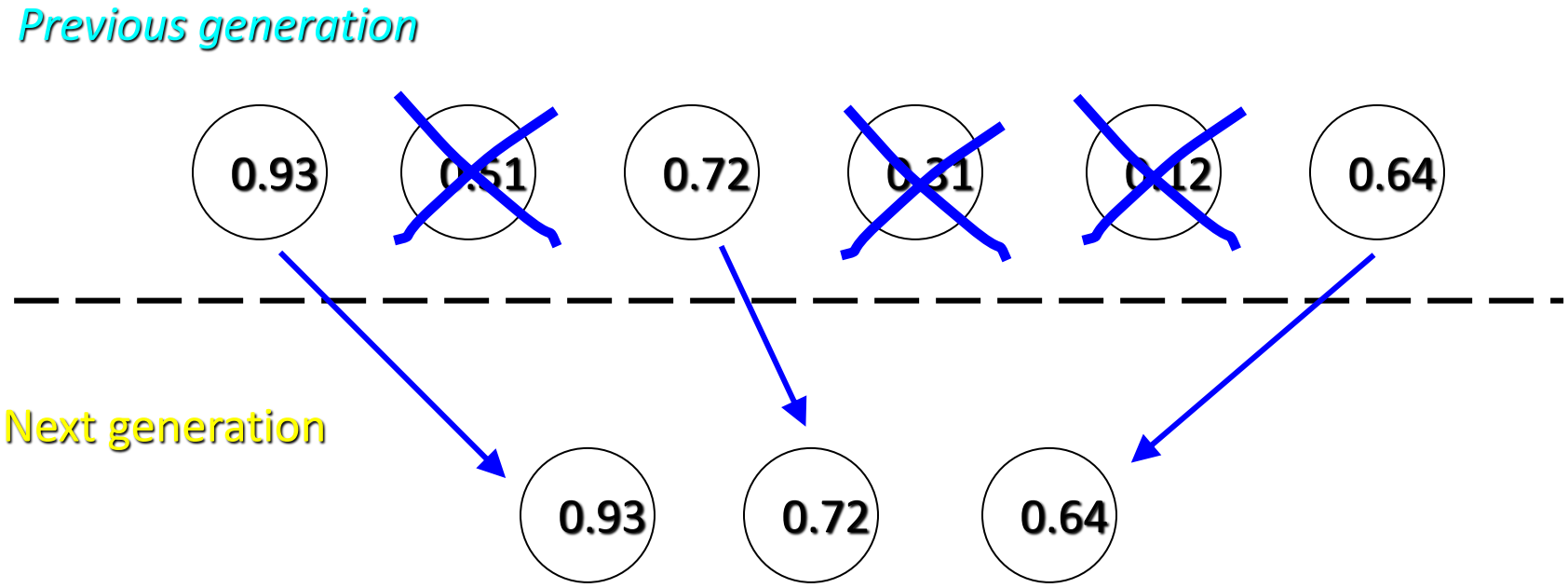


Replacement - Survival of The Strongest

- Cutoff selection:

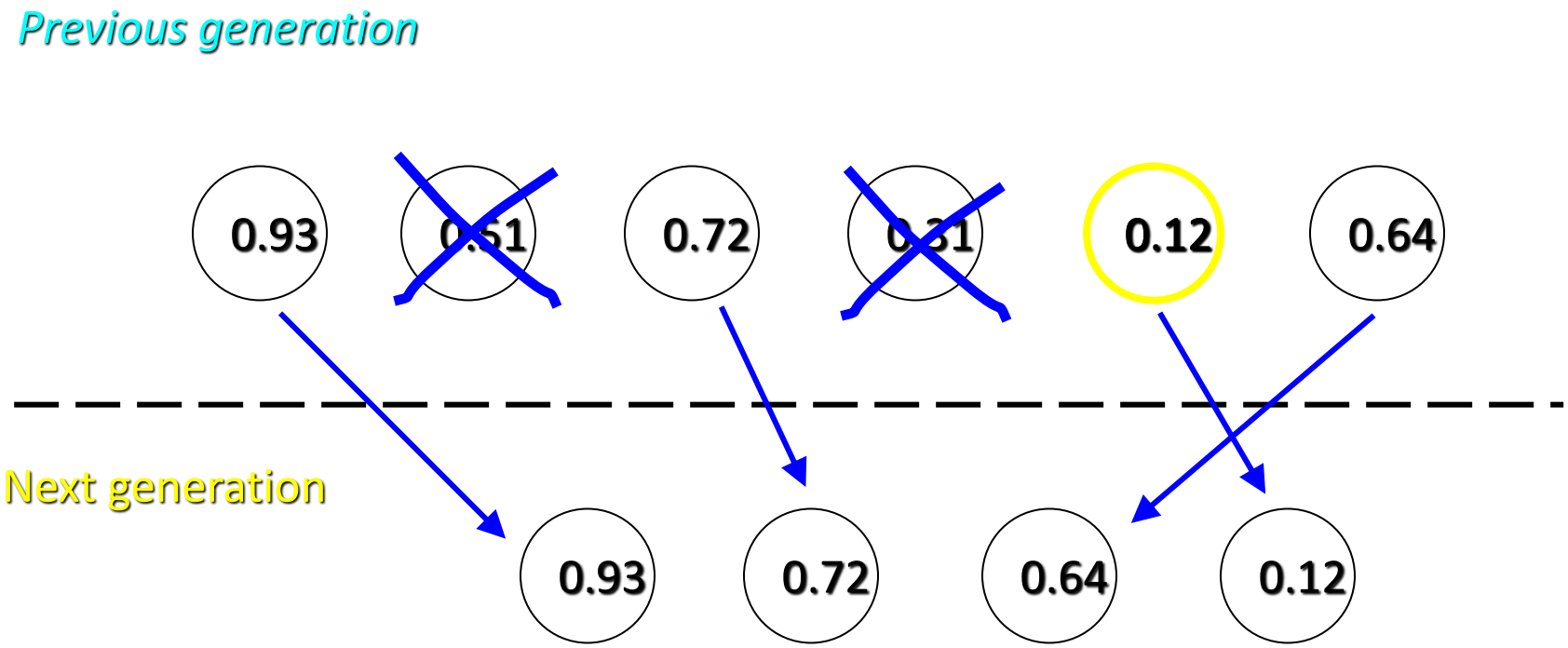
Select only those that are above a certain cutoff for the target function.

- Throw away the weak half of the population.



Replacement - Some Weak Solutions Survive

Mixing Strategy:
Select the strongest solutions with some weak ones.



Why ??

Replacement Strategies

- Three replacement schemas:
  - Generational Replacement (GGA):
    - Mate enough individuals to generate `pop_size` offspring
    - each individual survives for **exactly one generation**
    - the entire set of parents is replaced by the offspring
  - Steady-state Replacement (SSGA):
    - Specific number (K) of individuals are selected for reproduction, and offspring replace their parents in the next generation
  - Elitist Strategy (Elitism):
    - It is steady-state replacement, but keep best-so-far individuals

Elitism

- A fitness proportional selection doesn't guarantee survival of the fittest.

- Although it is beneficial for some algorithms to throw away the best so far to allow for a balance between **exploration (new solutions)** and **exploitation(find the best within the available solutions)**.

- Exploitation allows the algorithm to converge faster but without enough exploration, it might converge to a local optimum solution.

- To keep the best solution so far from being thrown away by crossover or mutation, the elitism option is used to keep one or more of the best solutions discovered so far and copy them to the next generation.

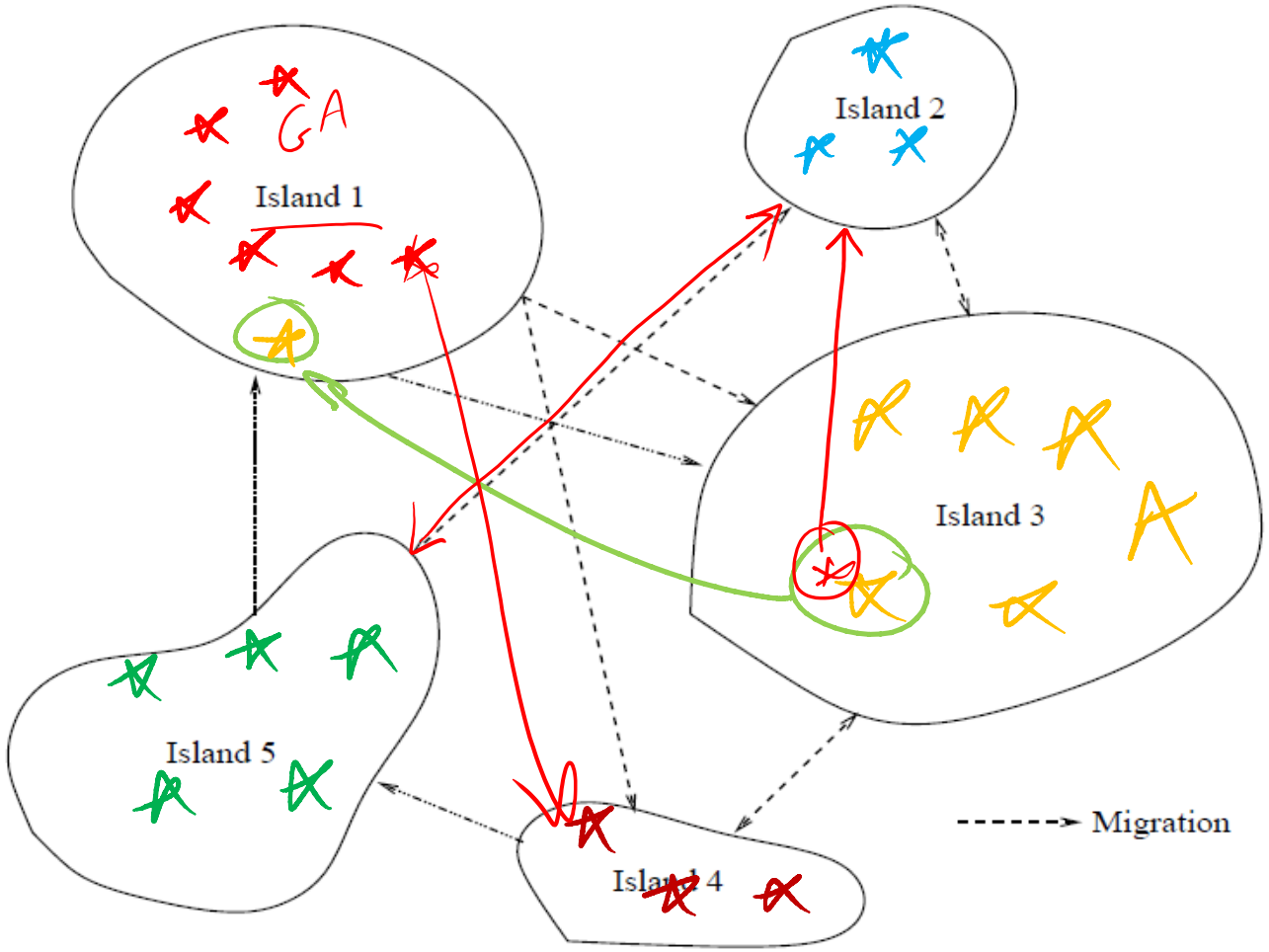
Population Models

- Generation Gap
  - The proportion of the population replaced from one Generation to the next one
  - Equals `1.0` for GGA
  - Equals `K/pop_size` for SSGA

- Generation Overlap
  - The amount of overlap for the population individuals between the current and new generations
  - Relationship between **Generation Gap** and **Generation Overlap ??**

Island Genetic Algorithm (I-GA)

- Each Island represents a separate GA with a separate sub-population
- One more operator is added: **Migration**
- Can be easily *parallelized* to run on multicore machines, clusters or GPU



Island Genetic Algorithm (I-GA)

Migration policies specify:

1. A **communications topology**, which determines the migration paths between islands
2. A **migration rate**, which determines the frequency of migration
   - If migration occurs too early, the number of good building blocks in the migrants may be too small to have any influence at their destinations
   - Usually, migration occurs when *each population has converged*
   - After exchange of individuals, all populations are restarted
3. A **selection mechanism**, to decide which individuals will migrate
4. A **replacement strategy**, to decide which individual of the destination island will be replaced

Island Genetic Algorithm (I-GA)

Based on the selection and replacement strategies, Island GAs can be grouped into two classes of algorithms:

- Static island GAs
  - A **topology** is used to determine migration paths
- Dynamic island GAs
  - Migration decisions are made **probabilistically**

Island Genetic Algorithm (I-GA)

Static Island GAs:

- Deterministic selection and replacement strategies
  1. A *good migrant* replaces a *bad individual*
  2. A *good migrant* replaces a *randomly selected individual*
  3. A *randomly selected migrant* replaces a *bad individual*
  4. A *randomly selected migrant* replaces a *randomly selected individual*

Island Genetic Algorithm (I-GA)

Dynamic Island GAs:

- **Migration** occurs at a probability
- **Destination** island is probabilistically selected
- Destination islands may use an **acceptance** strategy
  - *An immigrant is probabilistically accepted if its fitness is better than the average fitness of the island*