METAHEURISTICS

Population-Solution Based Metaheuristics

They could be viewed as an iterative improvement in a population of feasible solutions, As follows:

The use of a population of candidate solution often helps to achieve adequate diversification of the search process.

The population is initialized

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Based on some reproduction procedures, a new population of solutions is generated

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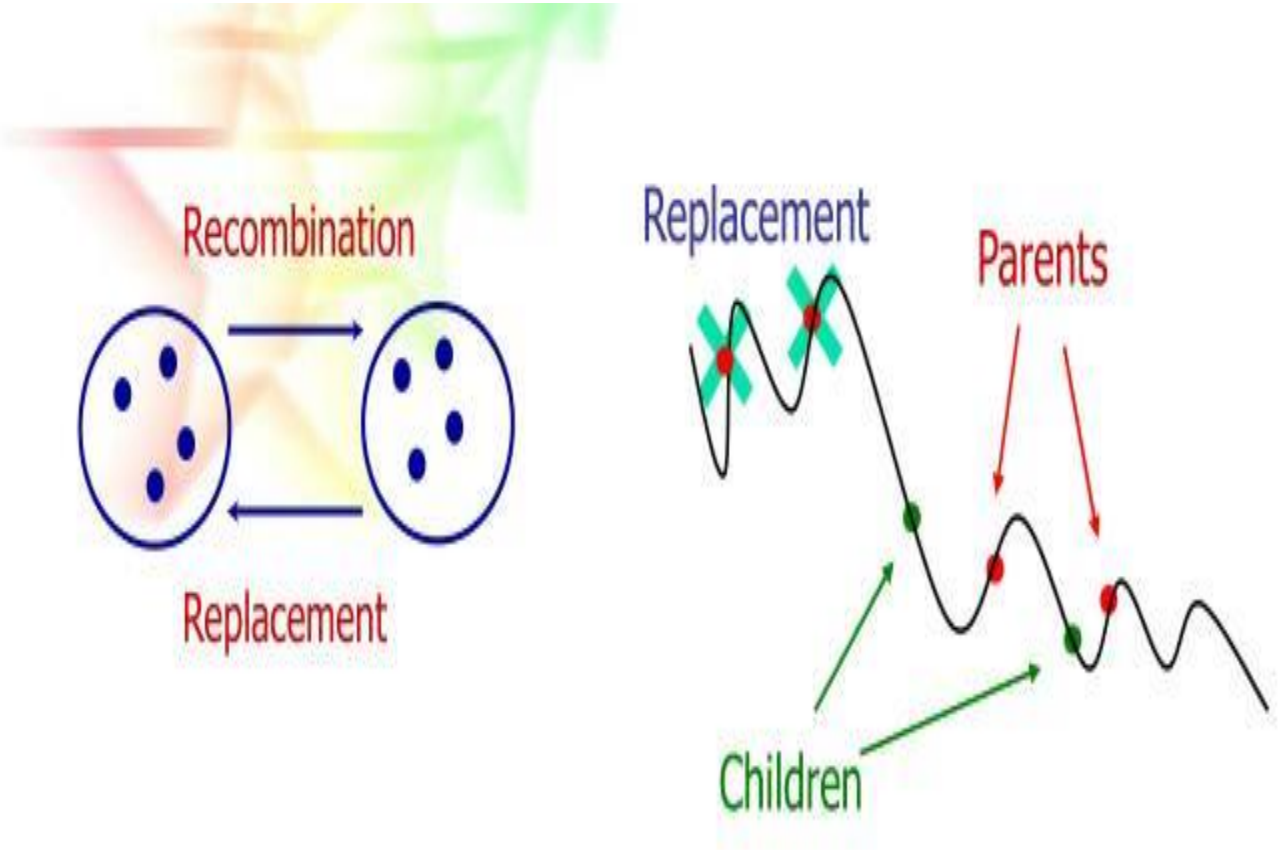
Based on some procedures (selection and replacement), a new population is integrated into the current one

The search process is stopped when a given condition is satisfied

Population-Solution Based Metaheuristic (P-metaheuristic)



E-G. Talbi, « Parallel Combinatorial Optimization », John Wiley & Sons, 2006.

Population-Solution Based Metaheuristic

P-metaheuristics differ in:

1. The way they perform the generation and the selection procedures.

- Memory
- Memoryless

2. The search memory they are using during the search.

Template of P-metaheuristics

$P = P_0$; /* Generation of the initial population */
$t = 0$;
Repeat
  Generate(P'_t); /* Generation a new population */
  P_{t+1} = Select-Population($P_t \cup P'_t$); /* Select new population */
  $t = t + 1$;
Until Stopping criteria satisfied
Output: Best solution(s) found.

Population-Solution Based Metaheuristic

The population is initialized

In the generation of the initial population, the main criterion to deal with is diversification. If the initial population is not well diversified, a premature convergence can occur for any P-metaheuristic.

This may happen if the initial population is generated using a greedy heuristic

The generation of the initial population in a way to optimize a given diversification criterion can be defined as an optimization problem. This problem may be as (or more) difficult as the original problem to solve.

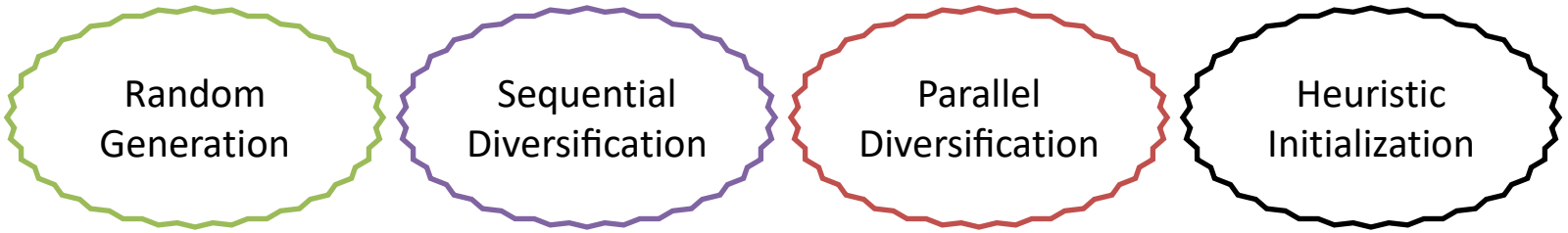
This is why in most of the cases, heuristic or metaheuristic algorithms are used to solve the optimization problem dealing with generation of a diversified population (maximizes its diversity Div(P)).

means that a population for an optimization problem converged too early, resulting in being suboptimal.

Population-Solution Based Metaheuristic

The population is initialized

Strategies dealing with the initialization of the population may be classified into four categories:



The initial population is generated randomly.

The solutions are generated in sequence in such a way that the diversity is optimized. This strategy is high computation cost. However, it ensures a good distribution of the population.

The solutions of a population are generated in a parallel independent way. This strategy gives a good overall random distribution of the population and does not require any evaluation of the objective function.

Any heuristic can be used to initialize the population.

This strategy may lose population diversity, which will generate a premature convergence of the population

Population-Solution Based Metaheuristic

Stopping Criteria

Many stopping criteria based on the evolution of a population may be used. Some of them are similar to those designed for S-metaheuristics.

Static procedure

Adaptive procedure

The end of the search may be known a priori. For instance, one can use a fixed number of iterations or a maximum number of objective function evaluations

the end of the search cannot be known a priori. One can use a fixed number of iterations (generations) without improvement

Some stopping criteria are specific to P-metaheuristics. They are generally based on some statistics on the current population or the evolution of the population. Mostly, they are related to the diversity of the population. It consists in stopping the algorithm when the diversity measure falls below a given threshold.

Population-Solution Based Metaheuristic

Selection strategy

The selection strategy addresses the following question:
"Which parents are chosen with a bias toward better fitness?"

The main principle of selection methods is:
"the better is an individual, the higher is its chance of being parent."

The worst individuals should not be discarded and they have some chance to be selected.

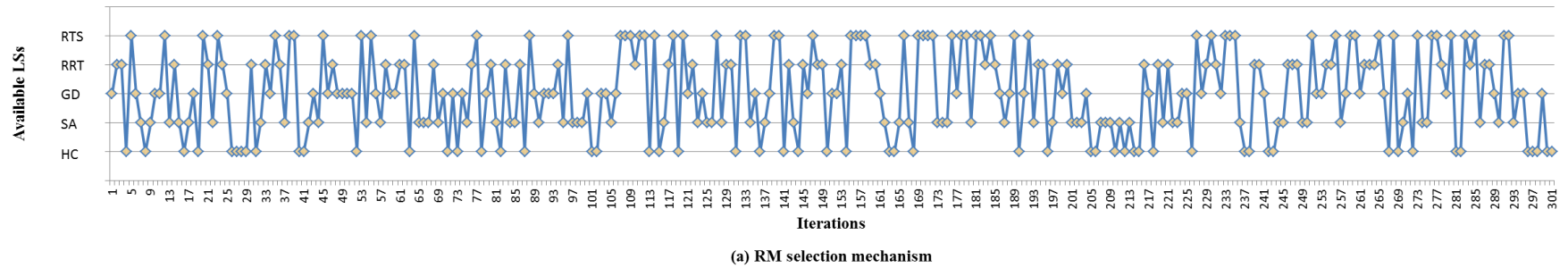
- Roulette Wheel Selection
- Stochastic Universal Sampling
- Tournament Selection
- Rank-Based Selection

Recently, different studies utilize an adaptive selection mechanism which takes into account the individual improvement history and the number of times it has been selected.

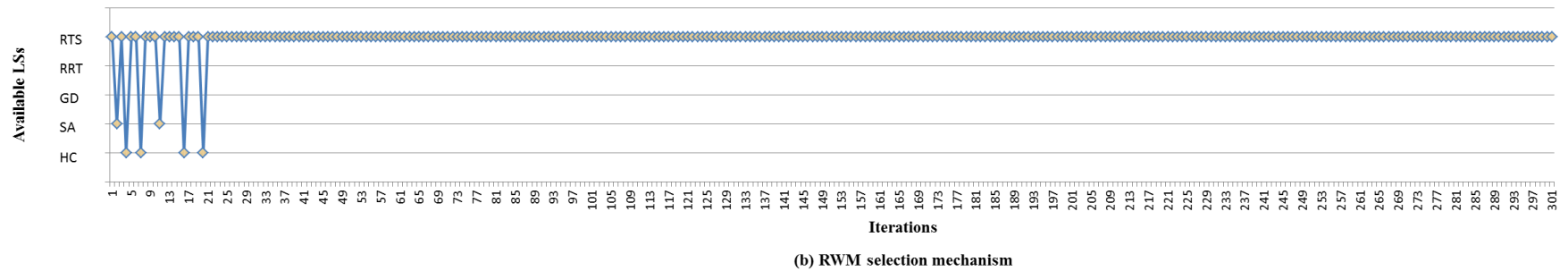
Population-Solution Based Metaheuristic

Selection strategy

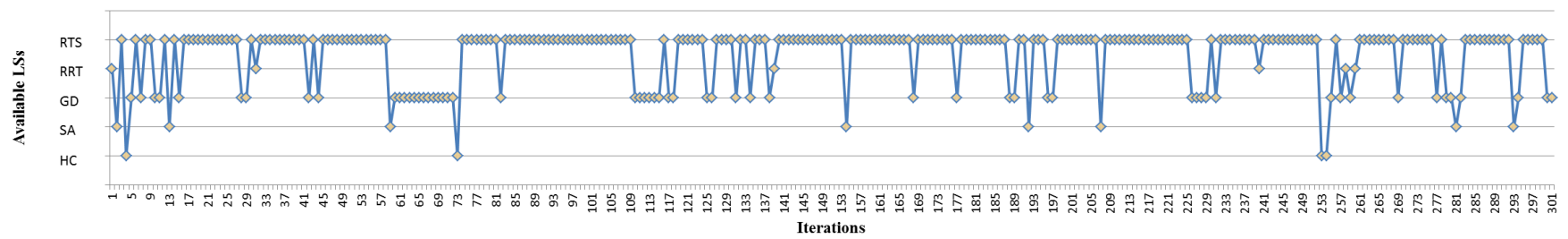
process of selecting during the search based on random, Roulette Wheel and adaptive selection mechanism.



(a) RM selection mechanism



(b) RWM selection mechanism



(c) MAB selection mechanism

Population-Solution Based Metaheuristic

Reproduction

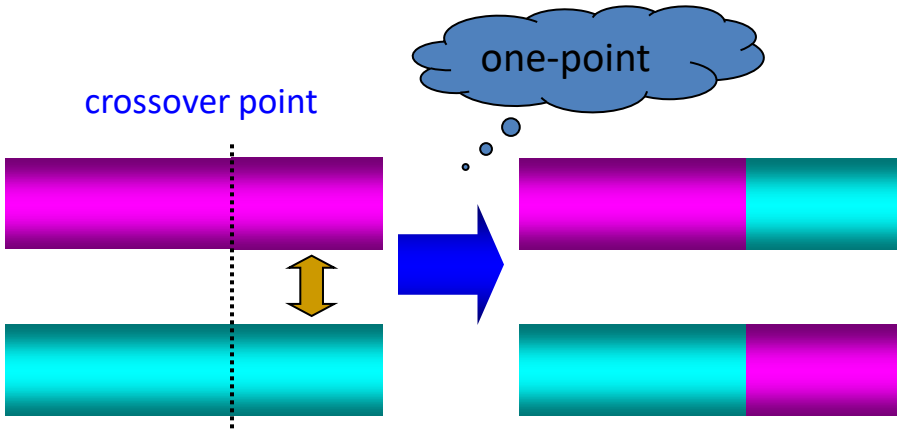
Once the selection of individuals to form the parents is performed, the role of the reproduction phase is the application of variation operators such as the mutation (unary operator) and crossover (binary operator). It generating a new solutions/offspring's.

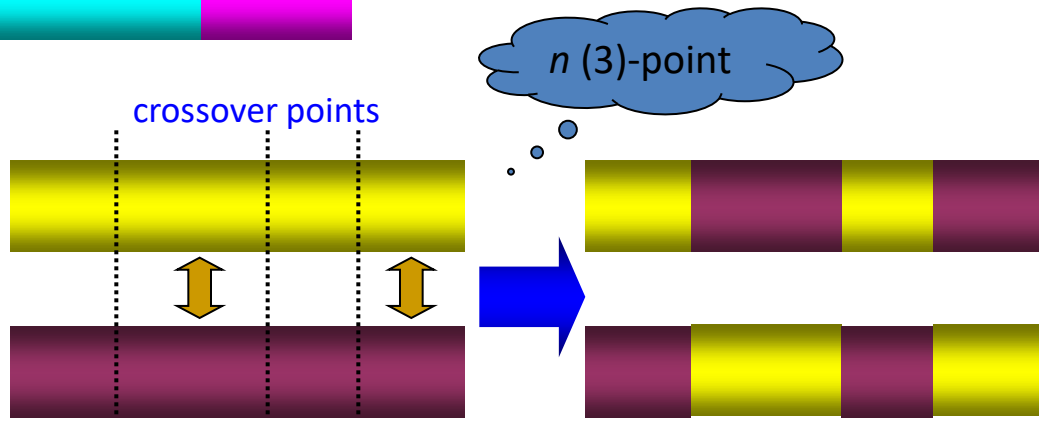
Crossover	the crossover operator is a binary and sometimes n-ary. The role of crossover operators is to inherit some characteristics of the two parents to generate the offsprings.

1. Combining two individuals (parents) to generate two offspring's
2. One-point crossover, *n*-point crossover, Uniform crossover, etc.

Heritability: The crossover operator should inherit a genetic material from both parents.

Validity: The crossover operator should produce valid solutions. This is not always possible for constrained optimization problems.



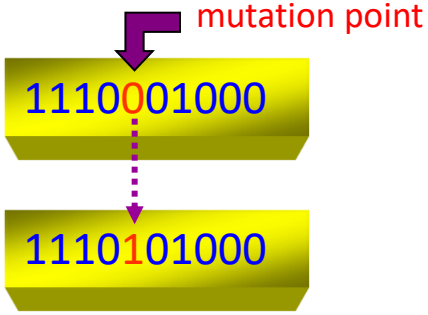


Mutations

Unary operators acting on a single individual. Mutations represent small changes of selected individuals of the population.

To add diversification into algorithm and make sure that the offspring's are different from their parents.

One point 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.

Population-Solution Based Metaheuristic

Replacement

The replacement phase concerns the survivor selection of both the parent and the offspring populations.

Generational replacement:

The replacement will concern the whole population of size μ. The offspring population will replace systematically the parent population. This strategy is applied in the canonical GA as proposed by *J. Holland*.

Steady-state replacement:

At each generation, only one offspring is generated. For instance, it replaces the worst individual of the parent population.

Examples of nature inspired algorithms

Genetic algorithm	Mimics the process of natural selection
Immune system	Mimics the process of the biological immune system
Ant colony	Mimics the behavior of ants when searching for food
Bee algorithm	Mimics the food foraging behavior of honey bee colonies
particle swarm optimization	Mimics the movement of organisms in a bird flock or fish school.
Harmony search	mimics the natural steps of musical improvisation taken by musicians to improve their musical tones.

THANK YOU

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