What is a Metaheuristic?
Optimization Problems
What is a Metaheuristic?

**Optimization problems**

- The many decision-making problems can be often expressed as an constrained *optimization problem* with some decision variables that are restricted by a set of constraints.

- Types of constrained optimization problems:
  - **Combinatorial problems**: When the decision variables are discrete
  - **Continuous problems**: When the decision variables are continuous
  - **Mixed problems**
What is a Metaheuristic?

Combinatorial Problems

- Examples of real-world combinatorial optimization problems include:
  - Assembly-line balancing problems
  - Vehicle routing and scheduling problems
  - Facility location problems
  - Facility layout design problems
  - Job sequencing and machine scheduling problems
  - Manpower planning problems
  - Production planning and distribution
  - Etc.
What is a Metaheuristic?

Combinatorial Optimization

- Combinatorial optimization problems are often easy to state but very difficult to solve.
- Many of the problems arising in applications are NP-hard, that is, it is strongly believed that they cannot be solved to optimality within polynomially bounded computation time.
What is a Metaheuristic?

Combinatorial Optimization

- Two classes of algorithms are available for the solution of combinatorial optimization problems:
  - Exact algorithms
  - Approximate algorithms
What is a Metaheuristic?

**Combinatorial Optimization**

- **Exact algorithms** are guaranteed to find the **optimal solution** and to prove its optimality for every finite size instance of a combinatorial optimization problem within an **instance-dependent run time**.

- In the case of NP-hard problems, in the worst case, **exponential time** to find the optimum.

- For most NP-hard problems the performance of exact algorithms **is not satisfactory**.
What is a Metaheuristic?

Combinatorial Optimization

- If optimal solutions cannot be efficiently obtained in practice, the only possibility is to trade optimality for efficiency.

- **Approximate algorithms**, often also called **heuristic methods** or simply **heuristics**, seek to obtain good, that is, near-optimal solutions at relatively low computational cost without being able to guarantee the optimality of solutions.
Metaheuristics
What is a Metaheuristic?

Metaheuristics

- A disadvantage of heuristic methods is that they:
  - either generate only a very limited number of different solutions, or
  - they stop at poor quality local optima, which is the case for iterative improvement methods.

- **Metaheuristics** have been proposed which try to bypass these problems.

- Metaheuristics apply to solve the problems known as of difficult optimization

- Available from the 1980s
What is a Metaheuristic?

**Metaheuristics**

- **Definition:**
  - A **metaheuristic** is a set of algorithmic concepts that can be used to define heuristic methods applicable to a **wide set of** different problems.
  - A **metaheuristic** can be seen as a **general-purpose heuristic method** toward promising regions of the search space containing high-quality solutions.
  - A metaheuristic is a general algorithmic framework which can be applied to different optimization problems with relatively **few modifications** to make them adapted to a specific problem.
What is a Metaheuristic?

Capability of Metaheuristics

- Metaheuristics have capability to be extracted from a local minimum
What is a Metaheuristic?

Metaheuristics

- The metaheuristics are from now on regularly employed in all the sectors of engineering,

- Examples of metaheuristics algorithms:
  - The evolutionary algorithms
  - The tabu search method
  - The ant colony optimization
  - The simulated annealing method
  - Etc.
What is a Metaheuristic?

Metaheuristics

- **OPTIMIZATION**
  - **COMBINATORIAL**
    - EXACT method (specialized)
    - APPROXIMATE method
  - **CONTINUOUS**
    - NON - LINEAR + (often) not analytically known
    - LINEAR programming

- **GLOBAL** method
- **LOCAL** method
- **METAHEURISTIC** (often with gradients)
- **CLASSICAL** specialized
References
What is a Metaheuristic?

References


The End