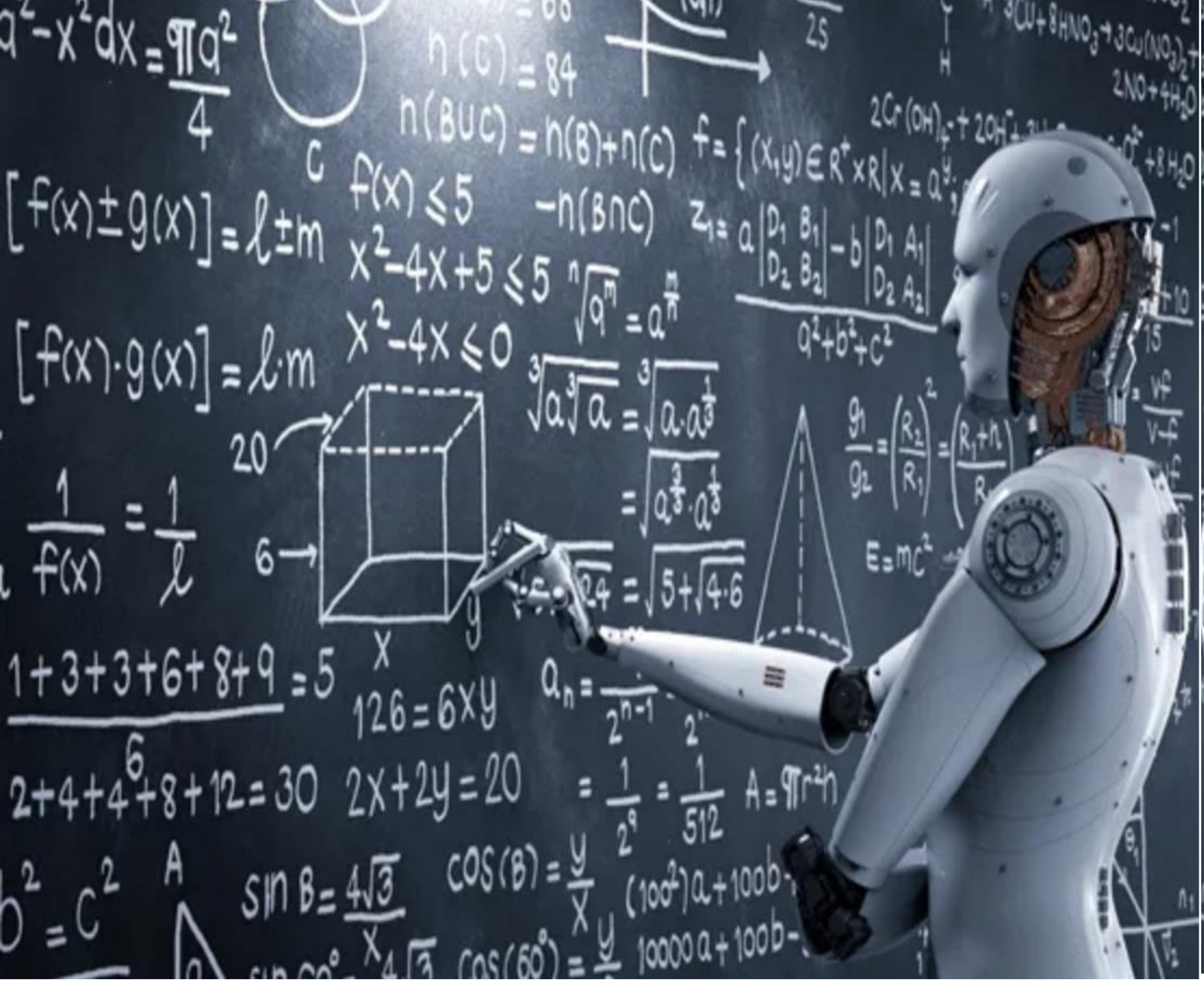
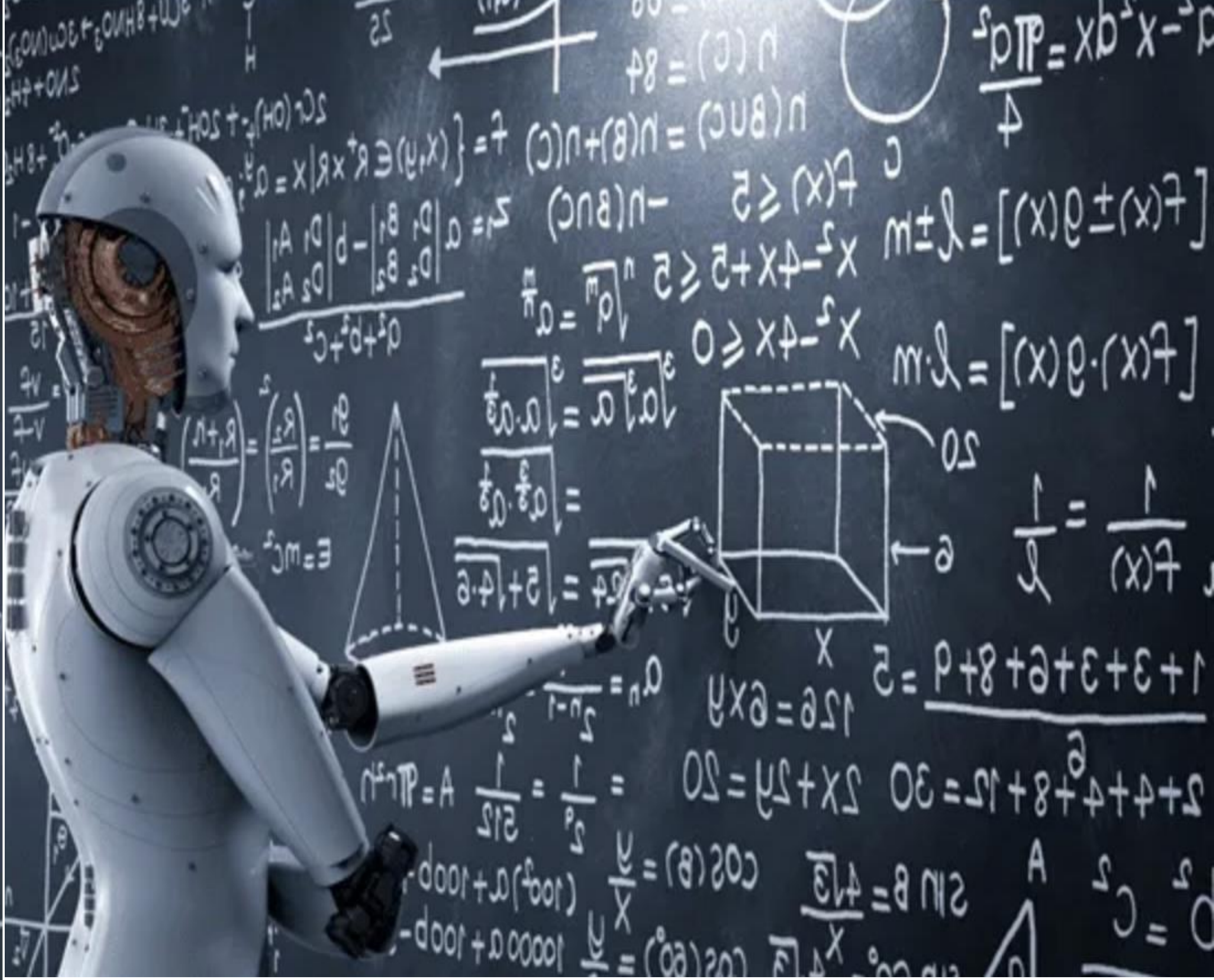




COOPERATIVE AND ADAPTIVE ALGORITHMS

Trajectory methods

HEURISTICS

- A Heuristic is simply a rule of thumb that hopefully will find a good answer.
- Why use a Heuristic?
  - Heuristics are typically used to solve complex (large, nonlinear, non-convex (i.e. contain local minima)) multivariate combinatorial optimization problems that are difficult to solve to optimality.
- Unlike gradient-based methods in a convex design space, heuristics are NOT guaranteed to find the true global optimal solution in a single objective problem, but should find many good solutions (the mathematician's answer vs. the engineer's answer)
- Heuristics are good at dealing with local optima without getting stuck in them while searching for the global optimum.

META-HEURISTICS

Meta-heuristics are algorithms that combine heuristics in a higher level framework aimed at efficiently and effectively exploring the search space

A metaheuristic search is a non-exhaustive search algorithm with internal heuristic.

A metaheuristic is formally defined as an iterative generation process which guides a subordinate heuristic by combining intelligently different concepts for exploring and exploiting the search space, learning strategies are used to structure information in order to find efficiently near-optimal solutions. [Osman and Laporte 1996].

FUNDAMENTAL PROPERTIES OF METAHEURISTICS

Metaheuristics are strategies that "***guide***" the search process.

The goal is to efficiently explore the search space in order to find (near-) optimal solutions.

Techniques which constitute metaheuristic algorithms range from ***simple local search*** procedures to ***complex learning*** processes.

Metaheuristic algorithms are ***approximate*** and usually non-deterministic.

FUNDAMENTAL PROPERTIES OF METAHEURISTICS

They may incorporate mechanisms to ***avoid getting trapped*** in confined areas of the search space.

The basic concepts of metaheuristics permit an ***abstract level description***.

Metaheuristics are ***not*** problem-specific.

Metaheuristics may make use of domain-specific knowledge in the form of heuristics that are controlled by the upper level strategy.

Today's more advanced metaheuristics use search experience (embodied in some form of memory) to guide the search.

META-HEURISTICS

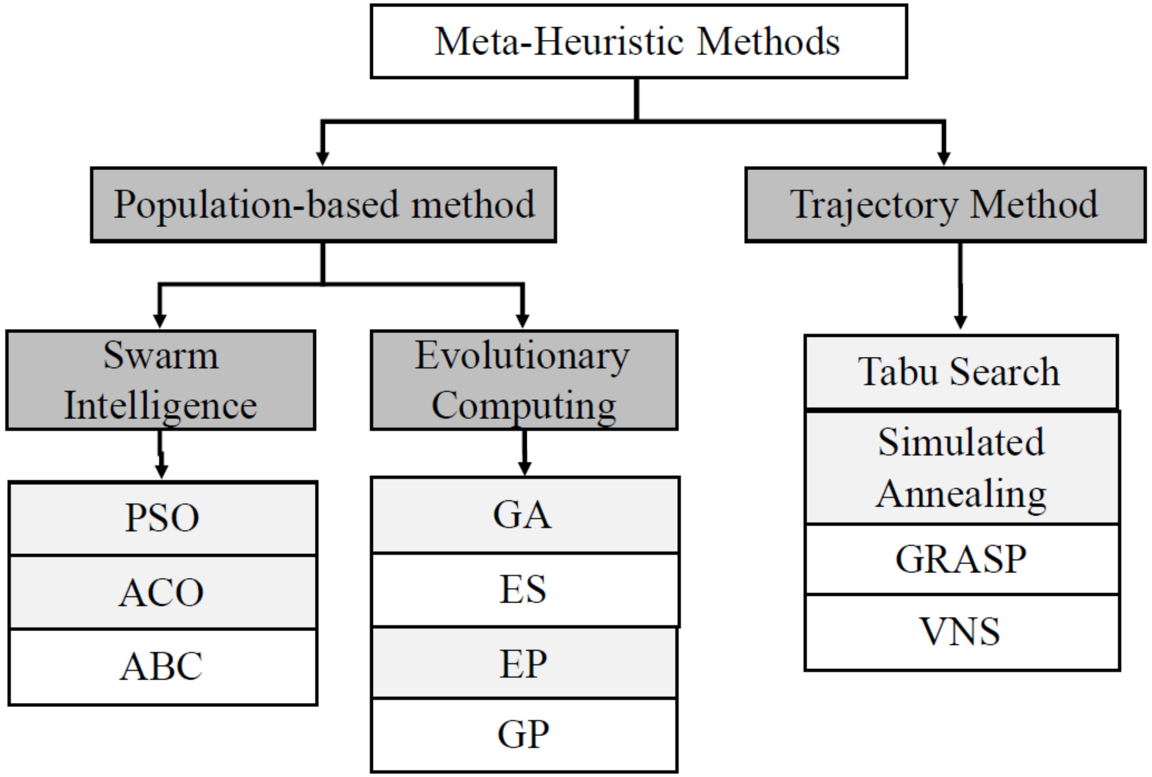
Metaheuristic searches are therefore often hybrid searches where the:

a. Search identifies neighborhoods that might be valid locations for the search term
b. Search intensifies the search in order to find the exact right answer.

Type:

- Trajectory methods, which handles one solution at a time
- Population-based, which handles multiple solutions.

META-HEURISTICS



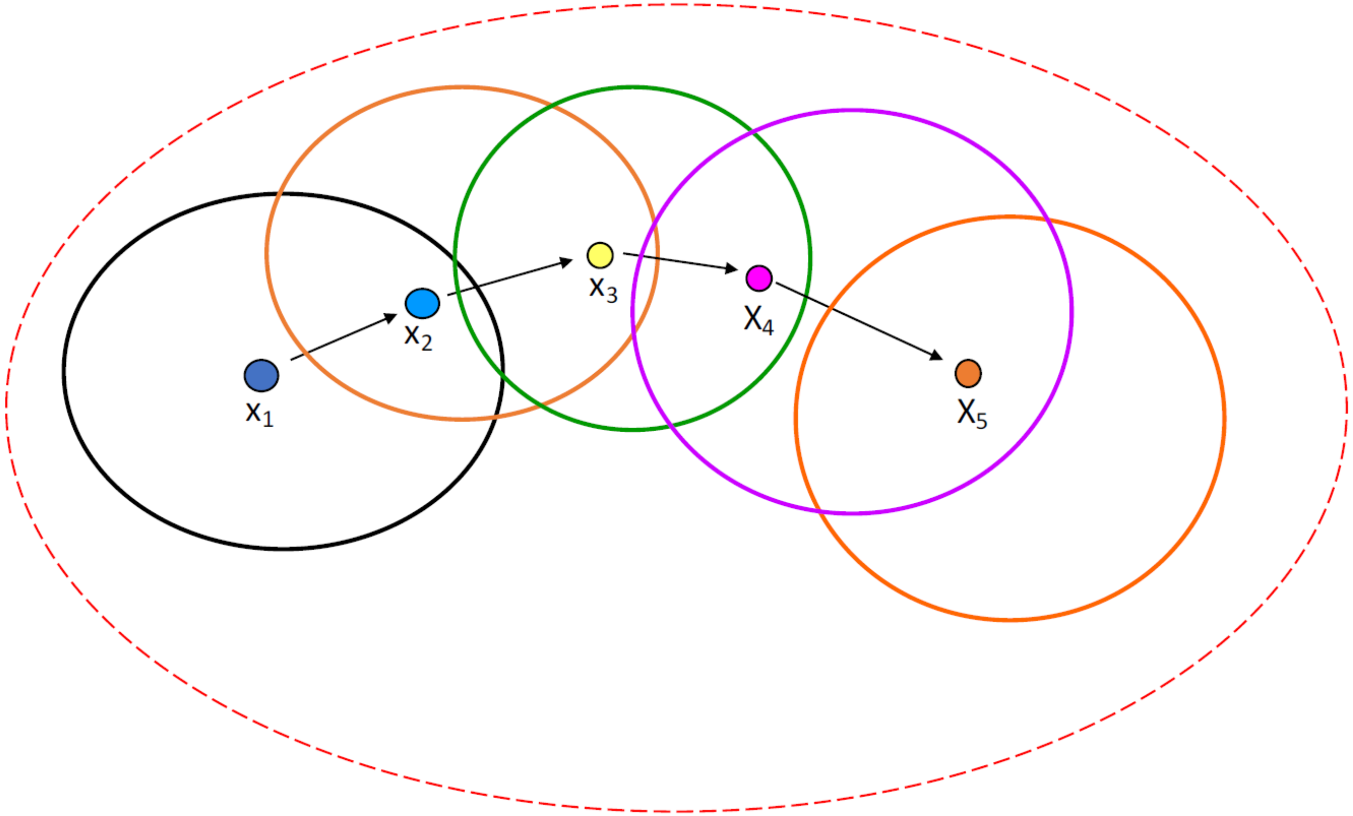
TRAJECTORY METHODS

Variants of local search methods to avoid getting stuck at local optimum.

It uses memory structures to:

- Escape local minima,
- Implement an explorative strategy. Avoid revisiting visited nodes.

TRAJECTORY METHODS



META HEURISTICS SEARCH

Learning from Physical Annealing

SIMULATED ANNEALING ANALOGY

- **Statistical Mechanics:** The behavior of systems with many degrees of freedom in thermal equilibrium at a finite temperature.
- **Combinatorial Optimization:** Finding the minimum of a given function depending on many variables.
- **Analogy:** If a liquid material cools and anneals too quickly, then the material will solidify into a sub-optimal configuration. If the liquid material cools slowly, the crystals within the material will solidify optimally into a state of minimum energy (i.e. ground state).
  - This ground state corresponds to the minimum of the cost function in an optimization problem.

PHYSICAL ANNEALING

Annealing is the thermal process of achieving low-energy state in a solid,

Physical annealing has been used since 5000 B.C.

A process used to make the material less fragile and improve its working properties,

Mainly used with metals, glass and crystals.

PHYSICAL ANNEALING

At high temperatures, molecules move freely

At low temperatures, molecules are “stuck”

The structural properties of the cooled material depend on the rate of cooling.

The ground state of the solid is obtained only if the maximum temperature is high enough and the cooling is done slowly

PHYSICAL ANNEALING

The annealing process involves:

- Heating the material, till it reaches the ***annealing temperature***,
- Holding the material at that temperature until it is even throughout,
- Cooling the material ***slowly*** (usually to room temperature)

PHYSICAL ANNEALING

The sequence of annealing times and temperatures is referred to as the ***annealing*** or ***cooling schedule***

The annealing schedule is very critical:

- Annealing times should be ***long enough*** for the material to undergo the required transformation,

- If the difference in the temperatures rate of change between the outside and inside of a material is too big, this may cause defects and cracks.

MORE ON ANNEALING AND RECRYSTALLIZATION