Department of CSE-H

MATHEMATICAL PROGRAMMING
22MT2101

HEURISTIC & META HEURISTIC TECHNIQUES

CO - 4

Session - 20

P. Murali Krishna
Asst. Professor

AIM OF THE SESSION

To familiarize students with the basic concept of heuristic and meta heuristic techniques.

INSTRUCTIONAL OBJECTIVES

This Session is designed to:

1. Describe the differences between these two techniques.
2. Describe the Importance of Infinite Dimensional Optimization

LEARNING OUTCOMES

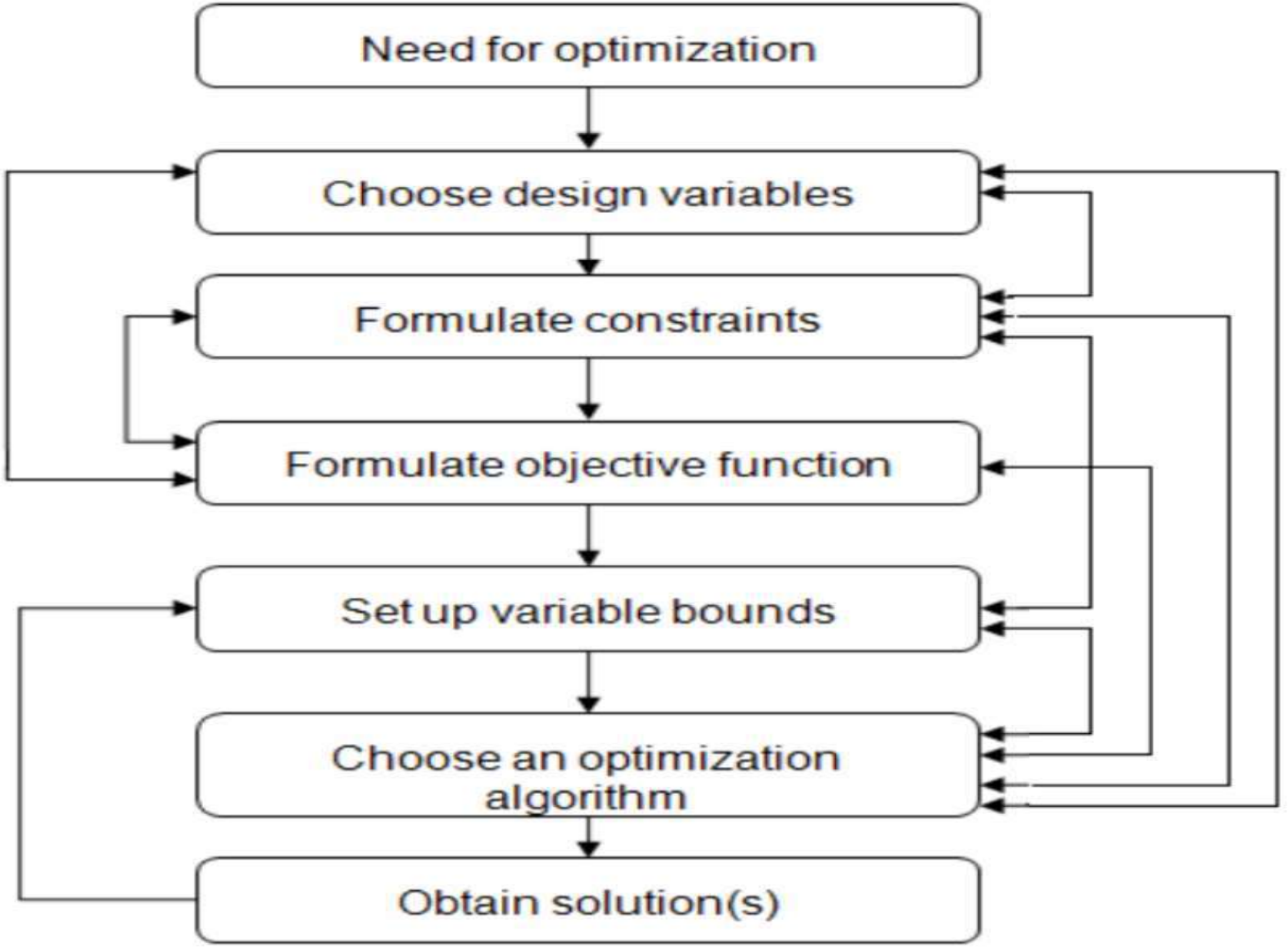
At the end of this session, student should be able to:

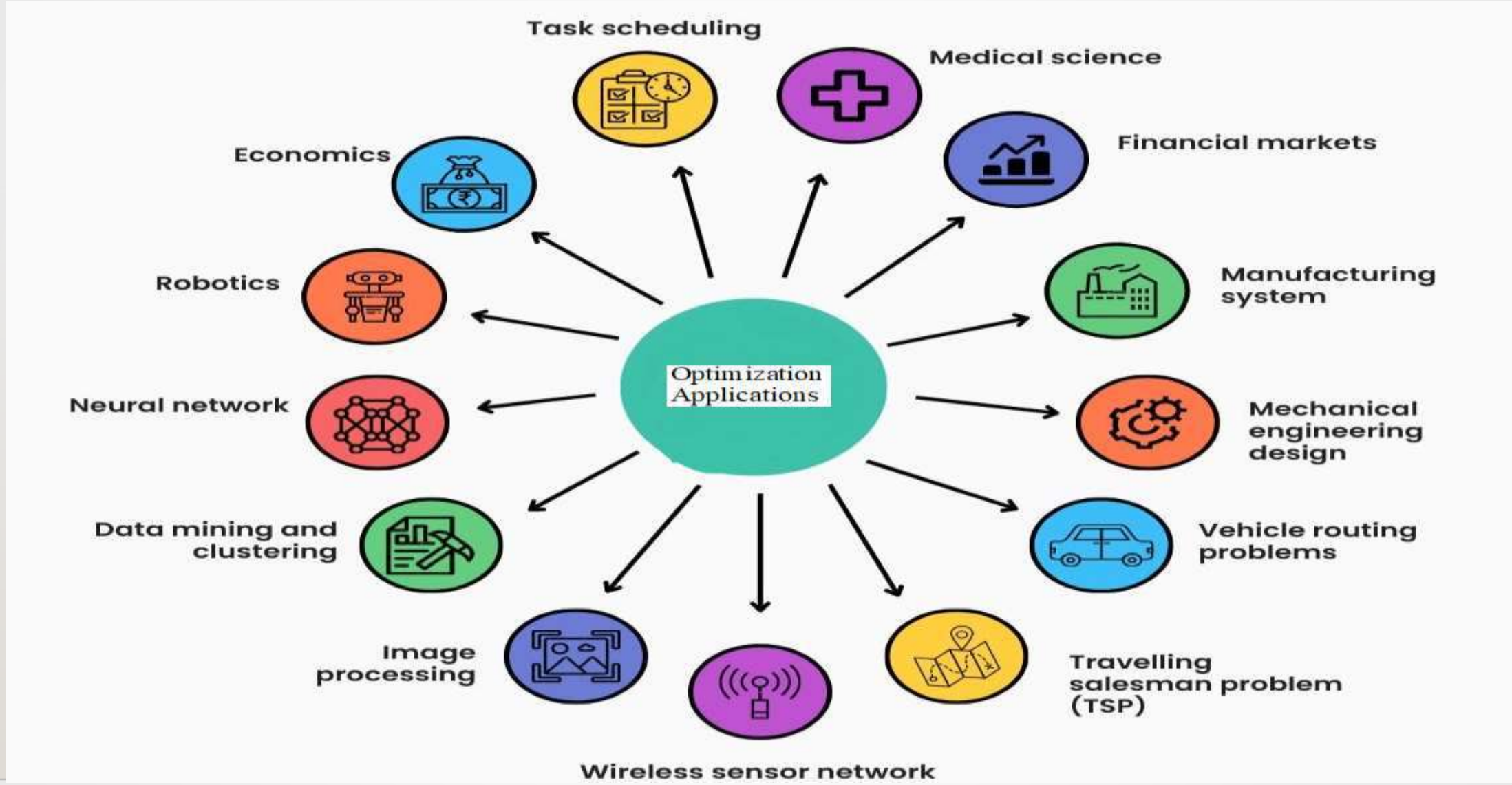
1. Describe various differences between the heuristic and meta heuristic techniques.
2. Summaries the Metaheuristic algorithms

MATHEMATICAL OPTIMIZATION

Mathematical optimization is the process of finding the best set of inputs that maximizes (or minimizes) the output of a function.
In the field of optimization, the function being optimized is called the objective function

$$\text{Max } Z = (4x_1 + 5x_2) + 12x_3 \qquad Objective\ \ Function$$
$$s.t.\ x_1 + x_2 + x_3 \geq 26 \qquad Inequality\ Constraint$$
$$x_1^2 + x_2^2 + x_3^2 + x_4^2 = 40 \qquad Equality\ constraint$$
$$1 \leq x_1 \geq 25 \qquad bounds\ on\ Variables$$
$$x_1 = 34 \qquad Initial\ Values$$


Need for optimization
Choose design variables
Formulate constraints
Formulate objective function
Set up variable bounds
Choose an optimization algorithm
Obtain solution(s)


Task scheduling
Medical science
Economics
Financial markets
Robotics
Manufacturing system
Optimization Applications
Neural network
Mechanical engineering design
Data mining and clustering
Vehicle routing problems
Image processing
Travelling salesman problem (TSP)
Wireless sensor network

SOLUTION STRATEGIES FOR OPTIMIZATION PROBLEMS

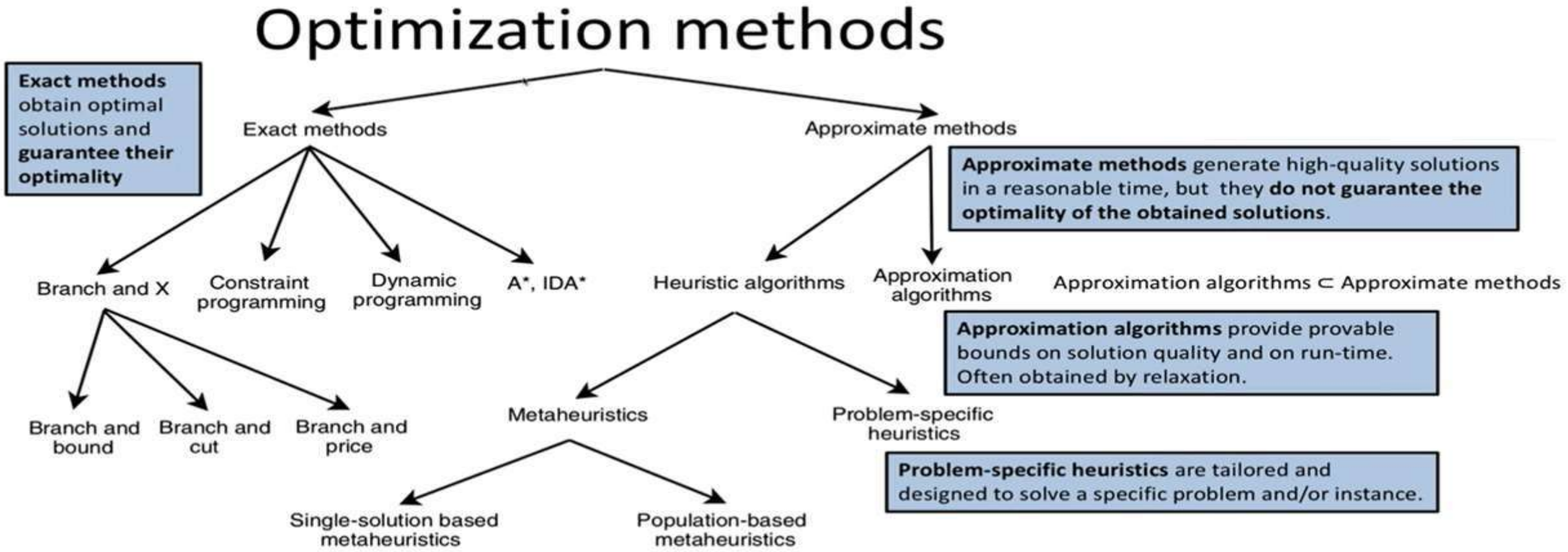
Methods to solve Optimization Problems	Nature of Solution
Linear or Non Lonear programming	Exact Solution
Branch and Bound	Exact Solution
Heuristic Method	Inexact, Near optimal Solution
Metaheuristic Method	Inexact, Near optimal Solution

In Heuristic and Metaheuristic method, we make a trade-off between solution quality and computational time

HEURISTIC METHOD VS METAHEURISTIC METHOD

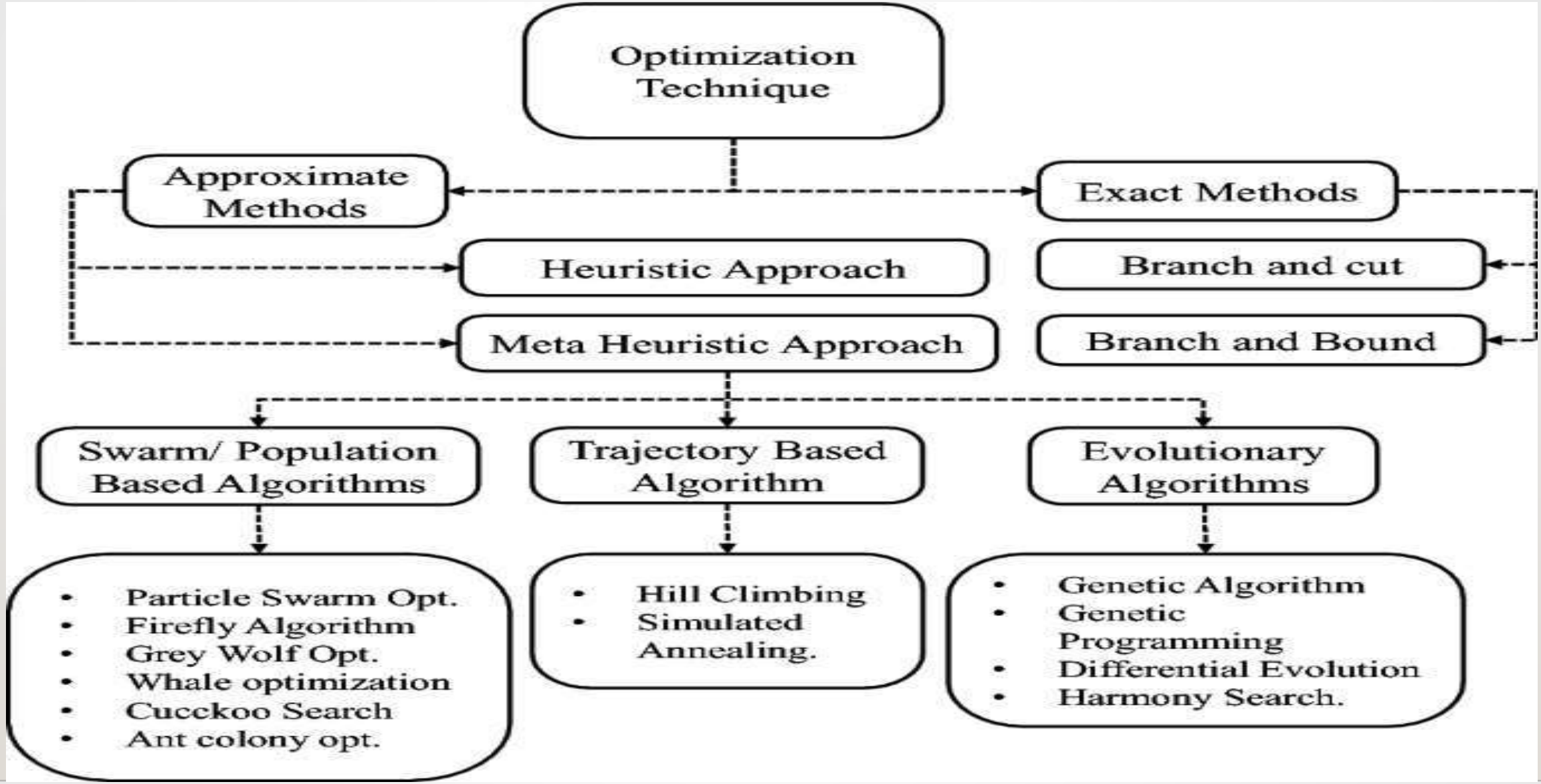
	Heuristic Method	Metaheuristic Method
Nature	Deterministic	Randomization + Heuristic
Type	Algorithmic	Nature Inspired, Iterative
Example	Nearest Neighbourhood Travelling salesman problems	Genetic Algorithm for Travelling Salesman Problems
Nature of Solution	Inexact, Near optimal Solution	Inexact, Near optimal Solution

Metaheuristics



Metaheuristics are **general-purpose algorithms** that can be applied to solve almost any optimization problem. Unlike approximation algorithms, metaheuristics **do not provide any bound** on how close the obtained solutions is to the optimal one. Unlike exact methods, metaheuristics **allow to tackle large-size problem instances by delivering satisfactory solutions in a reasonable time**

Source: Talbi, E. G. (2009). Metaheuristics: from design to implementation (Vol. 74). John Wiley & Sons.


Optimization Technique
Approximate Methods
Exact Methods
Heuristic Approach
Branch and cut
Meta Heuristic Approach
Branch and Bound
Swarm/ Population Based Algorithms
Trajectory Based Algorithm
Evolutionary Algorithms
Particle Swarm Opt.
Firefly Algorithm
Grey Wolf Opt.
Whale optimization
Cucckoo Search
Ant colony opt.
Hill Climbing
Simulated Annealing.
Genetic Algorithm
Genetic Programming
Differential Evolution
Harmony Search.

METAHEURISTIC

- The word ‘meta’ means higher level, where as the word ‘heuristics’ means to find.
- In computer science, metaheuristic designates a computational method that optimizes problem by iteratively trying to improve a candidate solution with regard to given measure of quality.
- Metaheuristic optimization is the best approach to optimizing such non-convex functions
- Metaheuristics do not guarantee an optimal solution
- Metaheuristics implement some form of stochastic optimization

Metaheuristics have fundamental characteristics can be summarized as:

- Heuristics can be employed by a metaheuristic as a domain-specific knowledge which is dominated by the upper-level strategy.
- Metaheuristics are not for a particular problem.
- Metaheuristics are usually approximate.
- Metaheuristics essentially can be described by abstraction level.
- Metaheuristics usually allow an easy parallel implementation.
- Metaheuristics extend from basic local search to advanced learning techniques.
- Metaheuristics may incorporate various mechanisms in order to avoid premature convergence.
- Emerging metaheuristics use guidance memory that preserves search experience.

Algorithmic framework for metaheuristics

```
Create one or more initial solutions
  While (stopping criterion not satisfied) do
     If exploit then
        Create new solution by exploitation step;
     Else
        Create new solution by exploration step;
     End
     Update best found solution ;
  End
  Return best found solution;
```

CLASSIFICATION OF METAHEURISTICS

- *Nature-inspired vs. non-nature inspired*
- *Population-based vs. single point search*
- *Dynamic vs. static objective function*
- *Memory usage vs. memory-less methods*

SELF-ASSESSMENT QUESTIONS

1. What are the differences between heuristics and metaheuristics?

(a) Heuristics can only be applied to one problem instance, and MHs to many of them

(b) Heuristics are ideas for problems and metaheuristics are ideas for heuristics

(c) Heuristics returns the global optimal solution, but MH are faster

(d) Heuristics are concrete and MH are more general

2. **Genetic algorithms are example of**

(a) heuristic

(b) Evolutionary algorithm

(c) ACO

(d) PSO

REFERENCES FOR FURTHER LEARNING OF THE SESSION

Reference Books:

1. Combinatorial Optimization: Exact and Approximate Algorithms by Luca Trevisan

2. Applied Mathematical Programming by Bradley, Hax, and Magnanti (Addison-Wesley, 1977).

3. Evolutionary Optimization Algorithm by Dan Simon, Willey Edition.

Sites and Web links:

1. https://archive.nptel.ac.in/noc/courses/noc18/SEM2/noc18-mg32/

2. . https://nptel.ac.in/courses/111/105/111105039/

THANK YOU

Team – Mathematical Progrmming