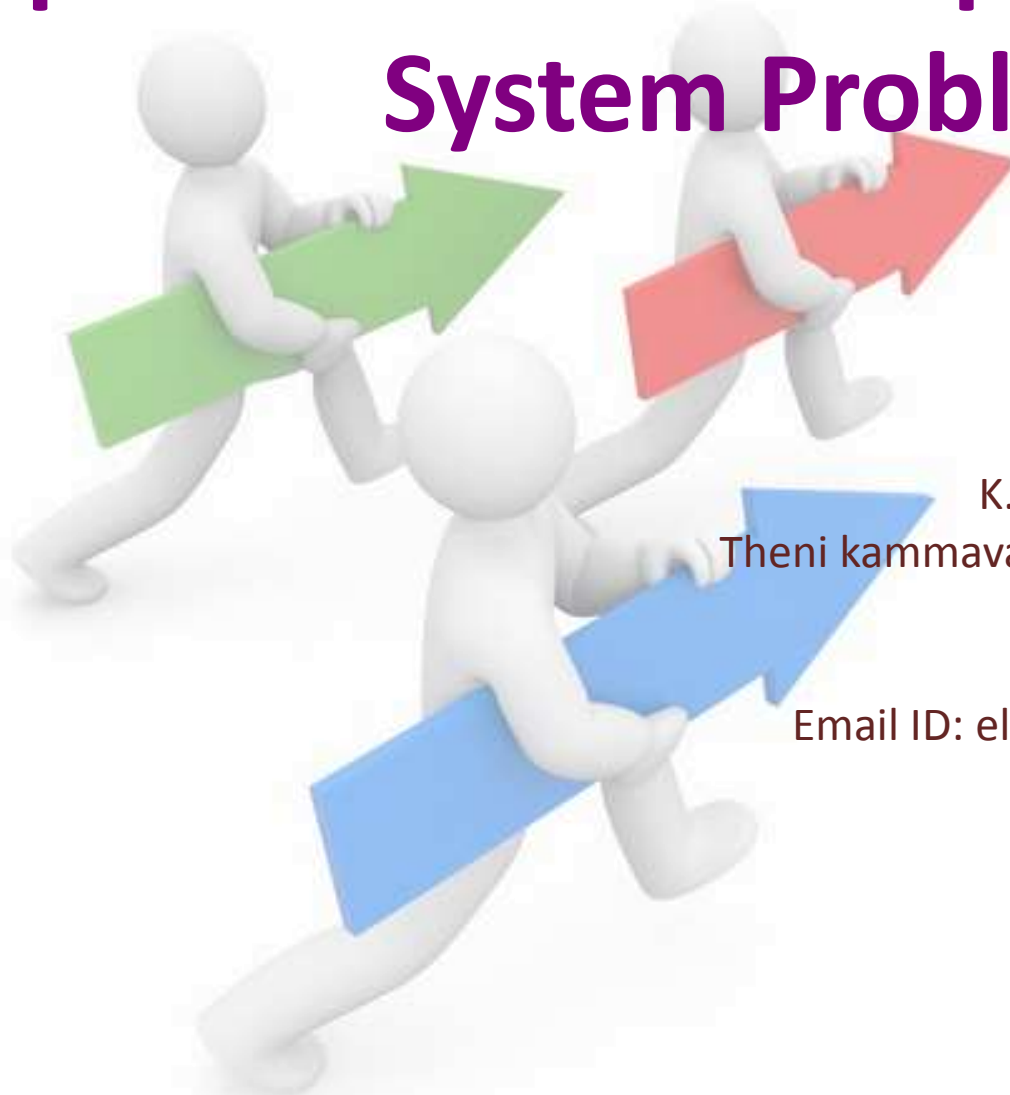


# Optimization Techniques for Power System Problems



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# Definition of Optimization



- Optimization is the mathematical discipline which is concern with finding the **Maxima** and **Minima** of function, possibly subject to the constraints for continuous and Differential functions.
- It is derived from the Latin Word '**Optimus**'

# Where can we use Optimization?

- Architecture
- Electrical Network
- Economics
- Material Design
- Image Processing
- Transportation
- Nutrition and Etc..



# Basic Terminologies



## Objective Function

It is expressed in mathematical function.

## Design variable & Decision Variable

- Values influence with Objective function.
- Aim is to find out the values Design/Decision Variables.

## Parameters

Constant Physical system.

## Constraints

Functional/Decision Variables/Physical limitation on Design

## Feasible Solution

Solution that satisfies all constraints

## Optimal Solution

Solution that give Optimum (Max or Min) objective function value.

# What do we Optimize?

- A Real Function of N Variables

$$f(x_1, x_2, x_3, \dots, x_n)$$

- With or Without constraints



# Classification of Optimization

Two of Classification

- **Static Optimization**

Variables have Numerical Values, Fixed with respect to time.

- **Dynamic Optimization**

Variables are function of time.

# Methodology of Optimization Technique



# Conti...



- What are the objectives?
- Is the proposed problem too narrow?
- Is it too broad?



# Conti...



- What data should be collected?
- How will data be collected?
- How do different components of the system interact with each other?

# Conti...



- What kind of model should be used?

- Is the model accurate?

- Is the model too complex?

# Conti...



- Do outputs match current observations for current inputs?
- Are outputs reasonable?
- Could the model be erroneous?

# Conti...



- What if there are conflicting objectives?
- Inherently the most difficult step.
- This is where software tools will help us!

# Conti...

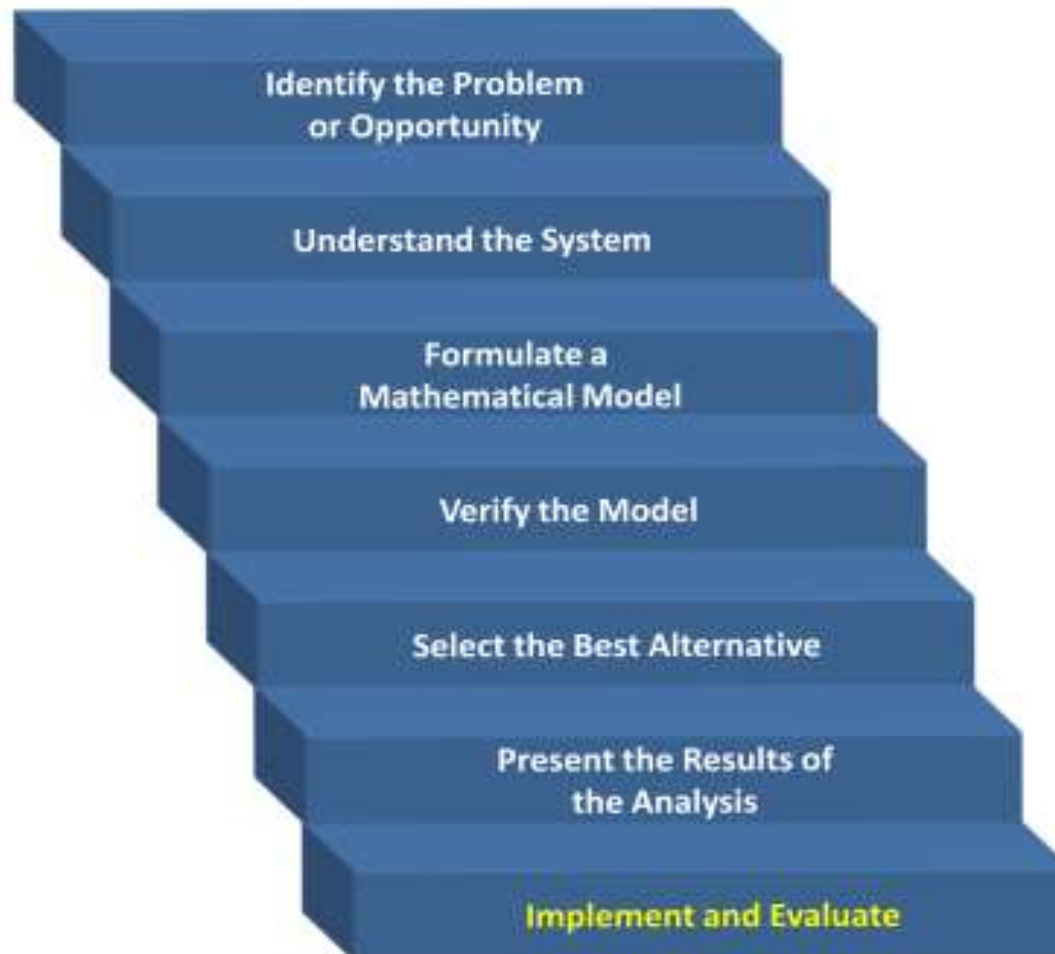


- Must communicate results in layman's terms.

- System must be user friendly!



# Conti...



- Users must be trained on the new system.
- System must be observed over time to ensure it works properly.

# Classical Solvers of Optimization Technique...

- Linear Programming
- Quadratic Programming
- Least Square method
- Non-Linear
  - Constraints
  - Un-constraints
  - Equation Solving
  - Curve Fitting



# Numerical methods of Optimization

- **Linear Programming** (" $f$ " is linear with linear equalities & inequalities)
- **Quadratic Programming** (" $f$ " allow in quadratic term with linear equalities & inequalities)
- **Integer Programming** (variables are in integer values)
- **Non-linear Programming** (" $f$ " & constrains are Non-linear)
- **Stochastic Programming** (some of the constraints are depends on Random variable)
- **Dynamic Programming** (splitting the problem into smaller sub problem)
- **Combinatorial Optimization** (" $f$ " Discrete)
- **Infinite-dimensional Optimization** (" $f$ " Infinite-dimension)
- **Constraint Satisfaction** (" $f$ " constant)

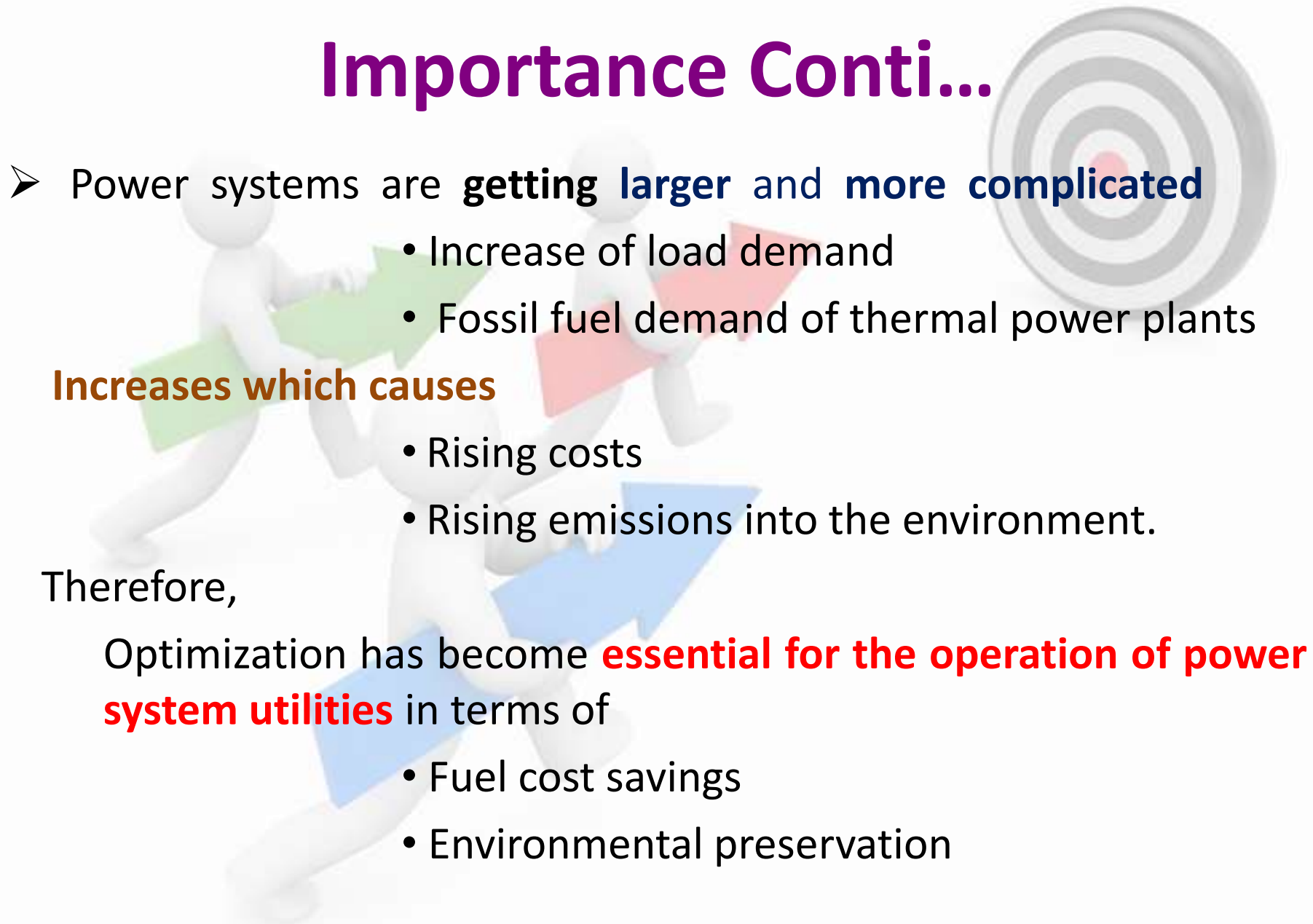


# Importance of Power System Optimization



- Power system engineering has the **longest history of development** among the **various areas of electrical engineering**.
- practical numerical optimization methods have played a very important role.
- Value contributed by system optimization  
Considerable in **economical terms with hundreds of millions of dollars** saved **annually in large utilities**.
  - Fuel cost
  - Improved operational reliability
  - System security

# Importance Conti...

- 
- Power systems are **getting larger and more complicated**
- Increase of load demand
  - Fossil fuel demand of thermal power plants

## **Increases which causes**

- Rising costs
- Rising emissions into the environment.

Therefore,

Optimization has become **essential for the operation of power system utilities** in terms of

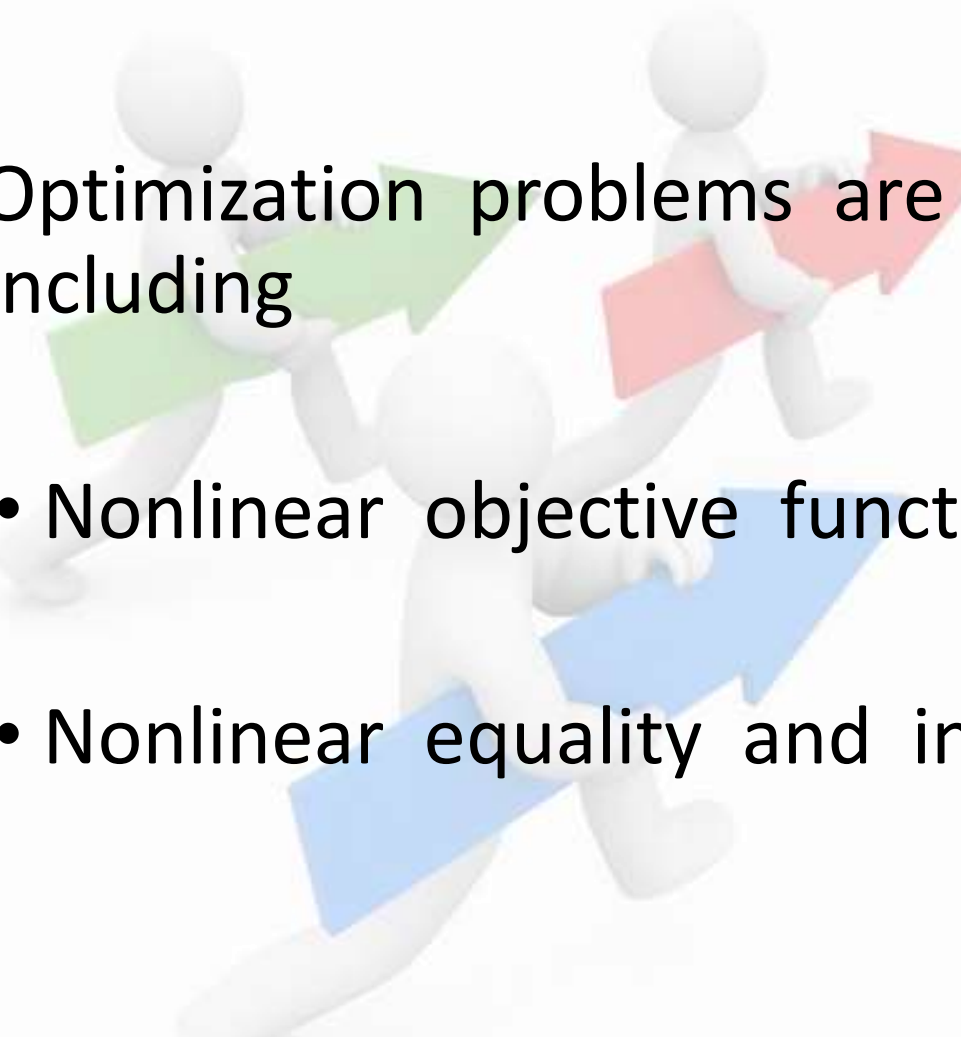

- Fuel cost savings
- Environmental preservation

# Optimization Aim and Focus...



- To **minimize the cost of power generation** in regulated power systems.
- To **maximize social welfare** in deregulated power systems, while **satisfying various operating** constraints.

# Optimization Problem Constraints...

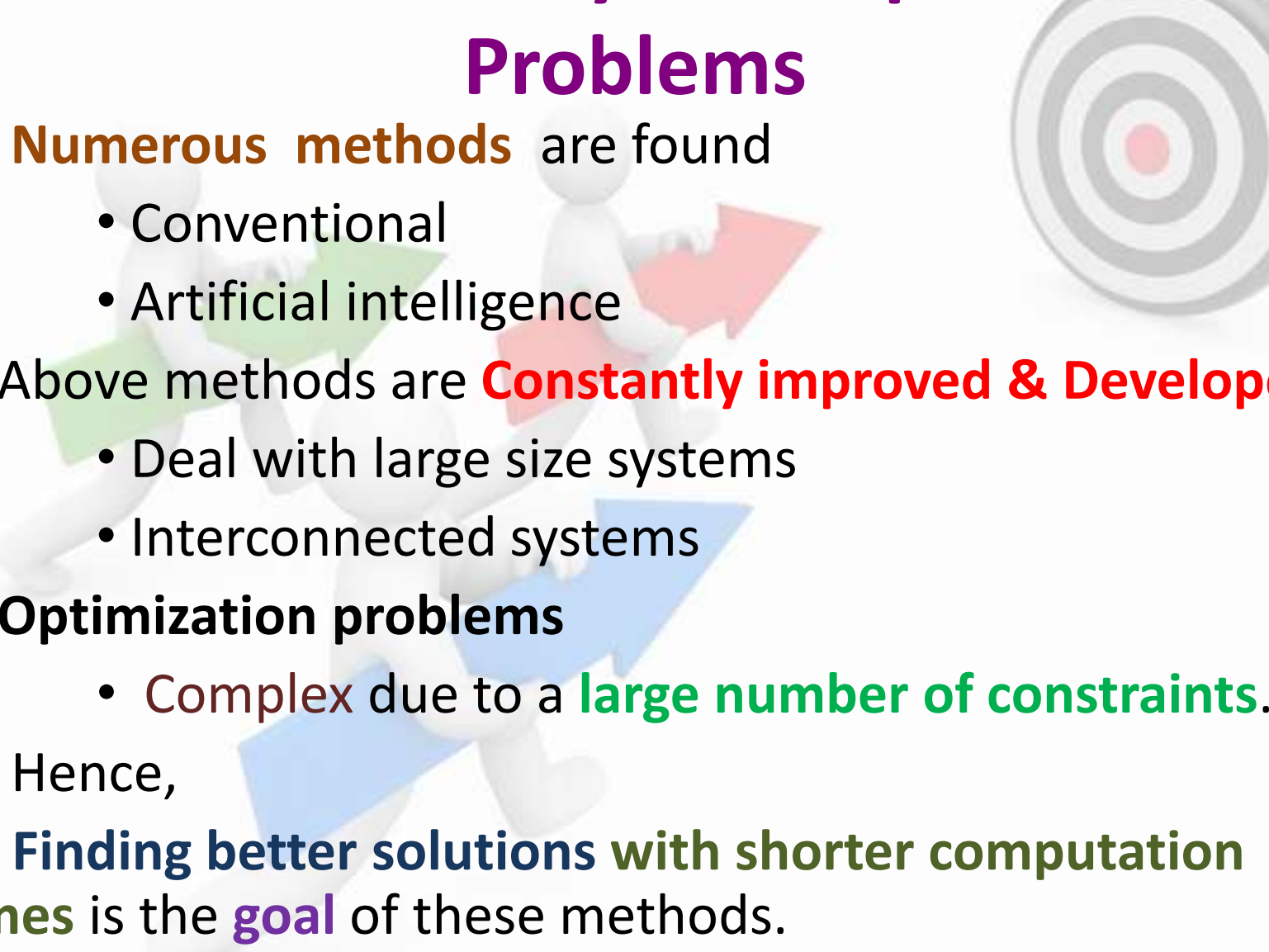
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- 
- Optimization problems are **nonlinear**, which including
    - Nonlinear objective functions
    - Nonlinear equality and inequality constraints.

# Optimization for Environmental Reasons



- **Dwindling fossil fuel** resources
  - Oil
  - Coal
  - Limitations to large scale renewable energy development
  - Controversial nuclear energy
  - Unsustainable levels of environmental emissions
- Optimization is **more important** for power system operation for **economical and environmental reasons.**

# To Solve Power System Optimization Problems

- 
- **Numerous methods** are found
    - Conventional
    - Artificial intelligence
  - Above methods are **Constantly improved & Developed**
    - Deal with large size systems
    - Interconnected systems
  - **Optimization problems**
    - **Complex** due to a **large number of constraints.**

Hence,

- **Finding better solutions with shorter computation times** is the **goal** of these methods.

# Several Optimization Issues

- Economic Dispatch (ED)
- Unit Commitment (UC)
- Hydrothermal scheduling
- Optimal power flow (OPF)
- Optimal Reactive power flow (ORDP)
- Voltage Stability
- Available Transfer Capability (ATC)
- FACTS Devices Placement
- Maintenance scheduling
- Distributed Generation
- Capacitor Placement in Radial Distribution Network(RDN)
- Phasor measurement unit (PMU) placement and etc..

# Artificial Intelligence As A New Trend In Optimization Problems


- widely used for solving optimization problems.

## ADVANTAGE

- Deal with **complex problems** that cannot be **solved** by conventional methods.
- Easy **to apply** due to their **simple mathematical structure**.
- Easy **to combine** with other methods to **hybrid systems adding the strengths** of each single method.
- Methods generally **simulate natural phenomena** or the **social behavior of humans or animals**.



# Expert Systems

- 
- Expert systems were developed **during the 1960s and 1970s** and **commercially applied throughout the 1980s**.
  - **Methodologies of expert systems**
    - Rule-Based Systems
    - Knowledge-Based Systems
    - Neural Networks
    - Object-Oriented Methodology
    - Case-Based Reasoning
    - System Architecture
    - Intelligent Agent Systems
    - Database Methodology
    - Modeling
    - Ontology.

# Expert Systems Conti...

- Expert systems are **combined with fuzzy** systems to **fuzzy-expert systems**.
- Expert systems are **combined with neural networks** to **neuron-expert systems**.
- Recently, with the **development of computer techniques**(expert systems are applicable to online applications).

# Fuzzy Systems

- Fuzzy systems were **developed in 1965** and have become popular in technical problem solving.
- It is Mathematical means of **describing vagueness** (imprecision or Indistinctness) **in linguistic terms** instead of an **exact mathematical description**.
- They are appropriate for **dealing with uncertainties** and **approximate reasoning**.
- Membership functions are **vaguely defined to represent the degree of truth of some events or conditions**.
- The values of membership functions **range from 0 to 1** in their linguistic form associated with imprecise concepts.

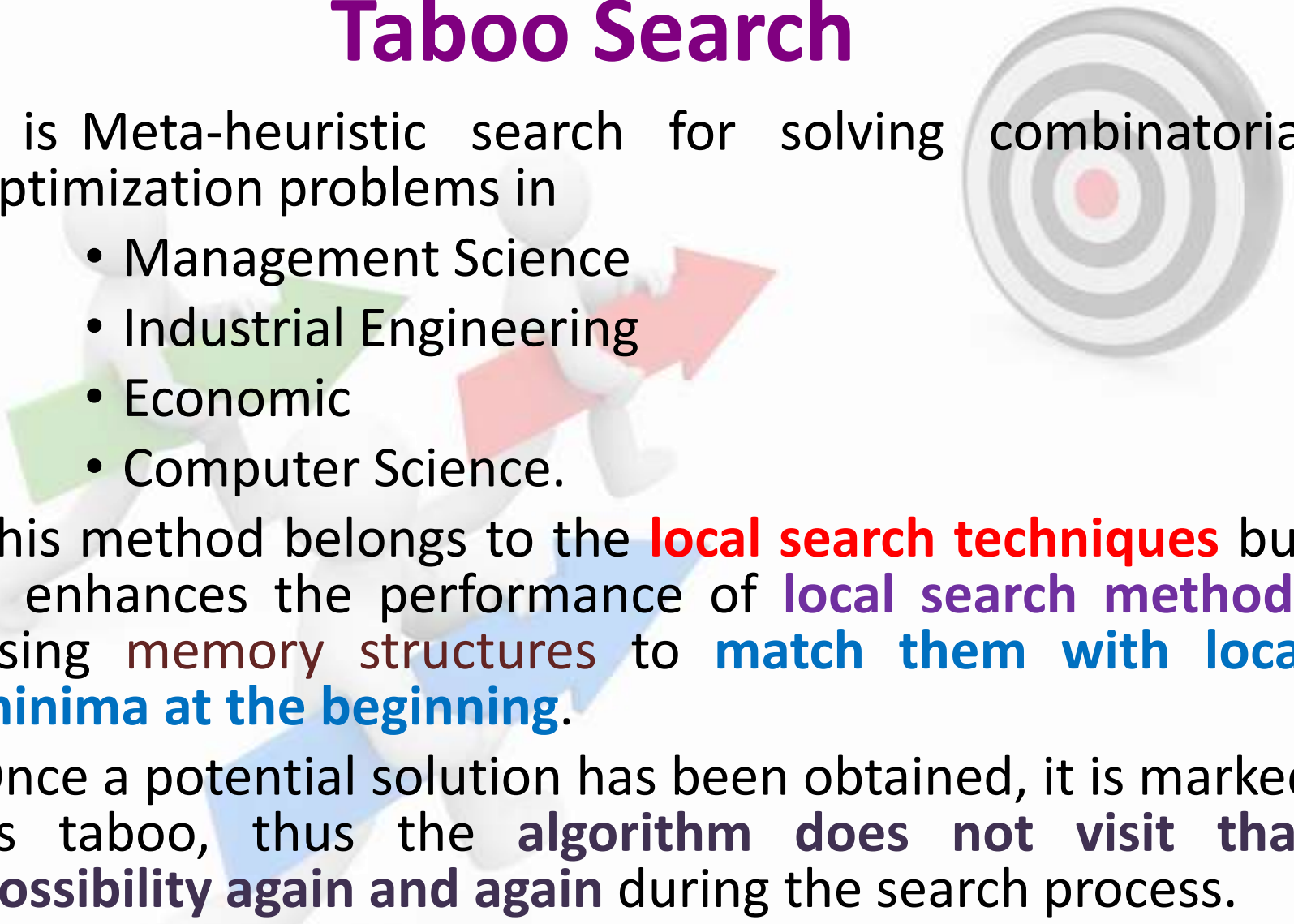
# Artificial Neural Network

- It is Mathematical models by **simulating the human biological neural network for processing information.**
- A Neural Network consists of **some layers of Artificial Neurons linked by weight connections.**
- Various Neural Networks by their structure such as
  - Feed Forward,
  - Back Propagation,
  - Radial Basis Function,
  - Recurrent Networks, etc.
- Each type has some specific work after being trained.
- It is infer a function from observations which is particularly useful for applications with the **complex tasks faced in real life** like function.
  - Approximation
  - Classification
  - Data Processing, etc.
- Its **primary advantage are capability to learn** algorithms
  - Online adaption of dynamic systems,
  - Quick parallel computation
  - Intelligent Interpolation of data.

# Simulated Annealing

- It is **Meta-heuristic search algorithm** for solving optimization problems by locating a **good approximation at the global optimum point** of a given function in a **search space**.
- This method simulates the **annealing in metallurgy** used for **heating** and **controlled cooling** of a metal for its **crystal resizing** and **effect reduction**.
- Simulated annealing was **developed in the 1980s** for solving optimization problems in a **discrete searching space** and **proved more efficient** than the method of exhaustive enumeration of the search space.

# Taboo Search

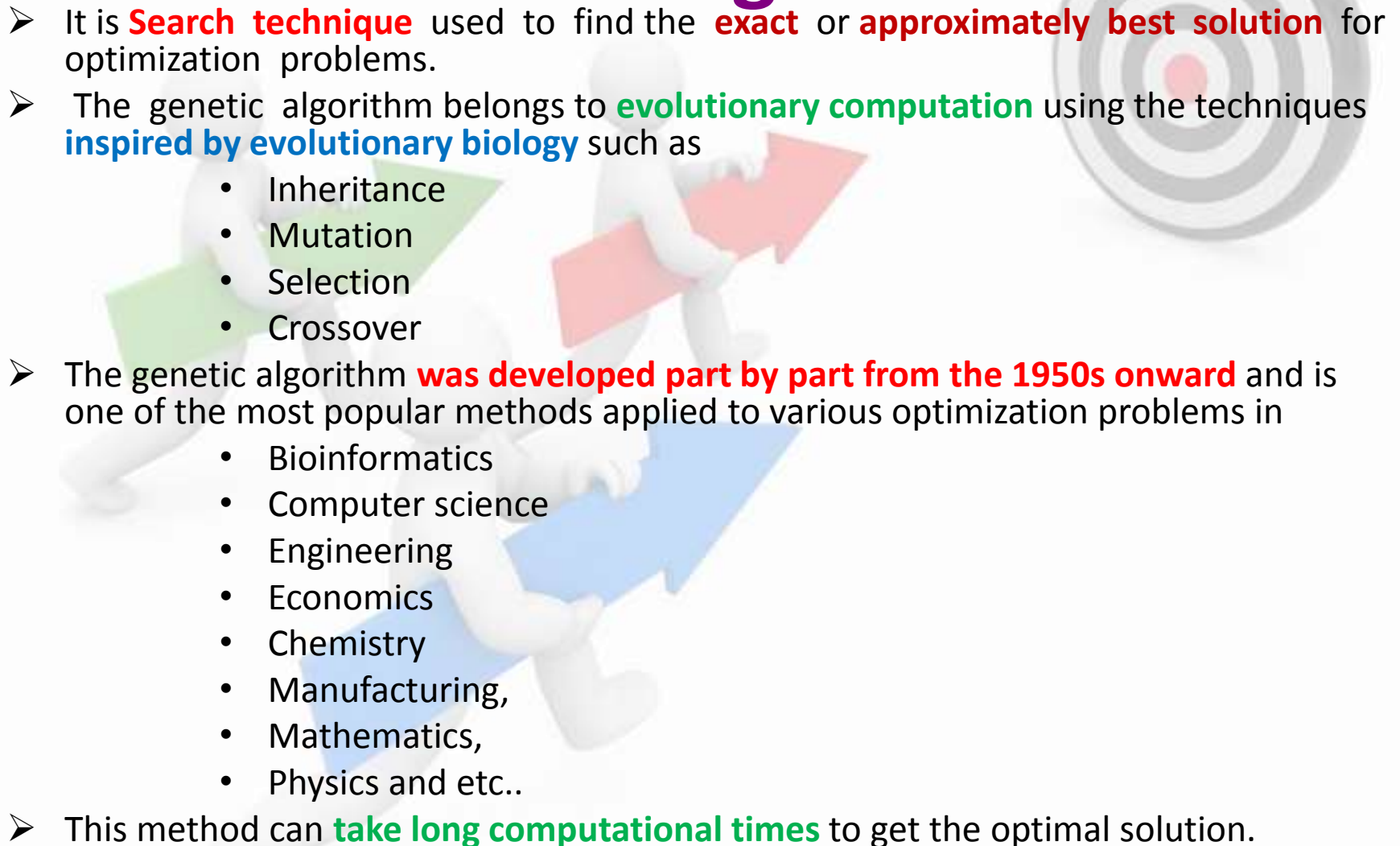
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- It is Meta-heuristic search for solving combinatorial optimization problems in
    - Management Science
    - Industrial Engineering
    - Economic
    - Computer Science.
  - This method belongs to the **local search techniques** but it enhances the performance of **local search methods** using **memory structures** to **match them with local minima at the beginning**.
  - Once a potential solution has been obtained, it is marked as taboo, thus the **algorithm does not visit that possibility again and again** during the search process.
  - Taboo search was **developed in the 1970s** and recently has been widely used for its powerful search capabilities.



# Ant colony Optimization Algorithm

- It is **Probabilistic technique** to solve optimization problems.
- It can be **reduced** to the problem of **finding the shortest paths** through **graphs based** on the behavior of ants in **finding food** for their **colony** by marking their **trails with pheromones**.
- The **shortest path is the trail** with the **most pheromone marks which the ants** will use to carry their food back home.
- This algorithm **was developed in 1991** and since then, many variants of this principle have been developed.

# Genetic Algorithm

- 
- It is **Search technique** used to find the **exact** or **approximately best solution** for optimization problems.
  - The genetic algorithm belongs to **evolutionary computation** using the techniques **inspired by evolutionary biology** such as
    - Inheritance
    - Mutation
    - Selection
    - Crossover
  - The genetic algorithm **was developed part by part from the 1950s onward** and is one of the most popular methods applied to various optimization problems in
    - Bioinformatics
    - Computer science
    - Engineering
    - Economics
    - Chemistry
    - Manufacturing,
    - Mathematics,
    - Physics and etc..
  - This method can **take long computational times** to get the optimal solution.



# Evolutionary Programming

- Evolutionary computation paradigms to find the **globally optimal solution** for an optimization problem.
- Evolutionary programming **was developed in 1960** placing emphasis on the **behavior** of the linkage between **parents** and their **offspring** rather than trying to **emulate the specific genetic operators** as observed in nature.
- The **main operators** of evolutionary programming consist of
  - Mutation
  - Evaluation
  - Selection
- Widely this method is used in different optimization techniques due to its powerful search capabilities.

# Particle Swarm Optimization

- It is **Heuristic algorithms** developed under emulation of **the simplified social behavior of animals in swarms** (fish schools and bird flocks).
- It is a **population based evolutionary algorithm** found to be efficient in solving continuous non-linear optimization problems.
- It provides a population-based search procedure, **in which individuals (particles) change their positions (states) over time.**
- It uses a **velocity vector** based on the social behavior of the individuals of the **population to update the current position** of each particle in the **swarm flying** in a **multidimensional search space** of a problem.
- During the flight each particle with a certain **velocity is dynamically adjusted** according to its **flight experience** and that of **its neighboring particles** to find the **best position for itself among its neighbors.**
- **Developed since 1995,** particle swarm optimization has been successfully applied in many researches and application areas such as
  - Engineering
  - Management system & Finance

# Differential Evolution

- It is Belonging to the **class of evolution strategy optimizers**, is a method of mathematical optimization of multidimensional functions to find the global minimum of a multidimensional and multimodal function fairly fast and reasonably robust.
- **Developed in the mid 1990s**, the differential evolution method is a **simple population based and stochastic function minimizer**.
- The **central idea** of this method is a **scheme to generate trial parameter vectors** by adding the **weight difference** between **two population vectors** to a **third one** that makes the scheme **completely self-organizing**.
- The **trial vector** is used for the next generation if it yields a reduction in the value of an objective function.

# Conti...

- In general, the methods based on Artificial intelligence are **continuously developed further** for other application in **different power system optimization problems**.
- Recently, **hybrid systems combining the strengths** of each single method have been favored by researchers due to various advantages over the single methods as presented above.

# Optimization Techniques

- Optimization techniques are **meta-heuristics** and these are **quite simple and inspired by simple concepts** typically related with the **corporeal phenomena of evolutionary concept and behaviour of animal** such meta-heuristics have the flexibility at local optima avoidance.
- Meta-heuristics are two classes they are

**Single solution based**

**Population based**

Simulated Annealing (SA) -- search process that starts with the **single candidate and improves over the iteration process.**

Genetic Algorithm (GA)

Artificial Bee Colony (ABC)

Particle Swarm Optimization (PSO)

Ant Colony Optimization (ACO)—All the above are **population based method**, where the **optimization is carried out by set of solutions**. Search process start with **random initial solution** and **improved over** the iteration process.

# Conti...

[simulated annaling.ppt](#)

[Differential Evolution Basics.pptx](#)

[DE.docx](#)

[ABC optimization.docx](#)





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