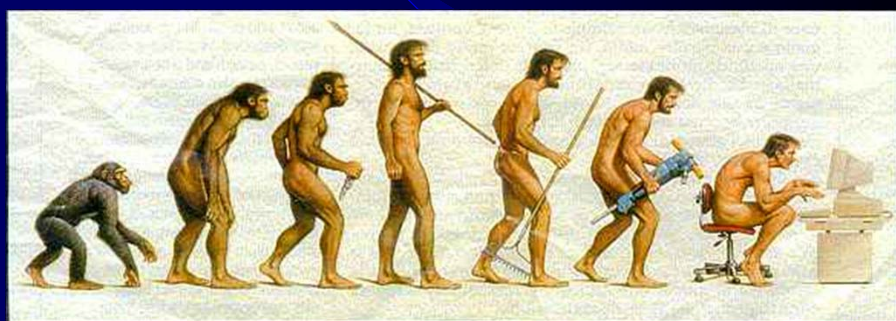
# Optimization and Evolutionary Computing

Lecture 1



## Outline

- Basic Optimization Background

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## Optimization

- It is the act of obtaining the best result under given circumstances.
- Engineering problems where the emphasis is on maximizing or minimizing a certain goal.

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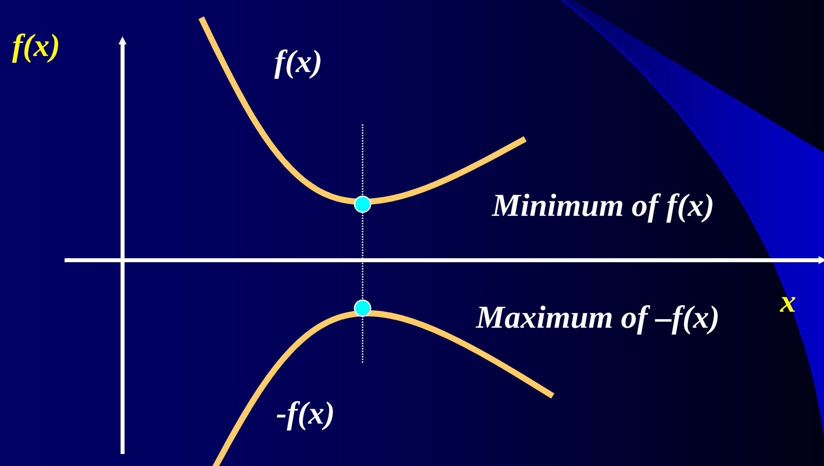
## Optimization (Contd.)

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## Optimization (contd.)

- The ***optimum*** seeking methods are also known as mathematical programming techniques and are generally studied as a part of ***operation research***.

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## Methods of Operation Research

- Mathematical Programming
- Stochastic Process Techniques
- Statistical Methods

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## Mathematical Programming Techniques

- Calculus Methods
- Calculus of variations
- Nonlinear Programming
- Geometric Programming
- Quadratic Programming
- Linear Programming
- Dynamic Programming
- Integer Programming
- Stochastic Programming
- Separable Programming
- Multi-objective Programming
- Network Methods: CPM/PERT
- Game Theory

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## Stochastic Process Techniques

- Statistical decision theory
- Markov Processes
- Queueing Theory
- Renewal Theory
- Simulation Methods
- Reliability Theory

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## Statistical Methods

- Regressional Analysis
- Cluster Analysis,
  Pattern Recognition
- Design of Experiments
- Discriminate Analysis
  (Factor Analysis)

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## Engineering Applications

- Design of Aircraft and Aerospace Structures for minimum weight
- Finding the optimal trajectories of space vehicles
- Design of Civil engineering structures – frames, foundations, bridges, towers, chimneys and dams for minimum cost

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## Engineering Applications (Contd.)

- Minimum weight design of structures for earthquake, wind and other types of random loading
- Design of water resources systems for maximum benefit
- Optimal plastic design of structures
- Optimum design of linkages, cams, gears machine tools and other mechanical components

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## Engineering Applications (Contd.)

- Selection of machining conditions in metal cutting processes for minimum production cost.
- Design of material handling equipment like conveyors, trucks and cranes for minimum cost.
- Design of pumps, turbines and heat transfer equipment for maximum efficiency

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## Engineering Applications (Contd.)

- Optimum design of electrical machinery like motors, generators and transformers
- Optimum design of electrical networks.
- Shortest route taken by a salesmen visiting different cities during one tour
- Optimal production planning, controlling and scheduling

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## Engineering Applications (Contd.)

- Analysis of statistical data and building empirical models from experimental results to obtain the most accurate representation of the physical phenomenon.
- Optimum design of chemical processing equipment and plants
- Design of optimum pipe line networks for process industries

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## Engineering Applications (Contd.)

- Selection of site for an industry
- Planning of maintenance and replacement of equipment
- Inventory control
- Allocation of resources or services among several activities to maximize the benefit
- Optimum design of control systems.

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## Statement of an Optimization Problem

- An Optimization or a mathematical programming problem can be stated as follows

Find $\boxed{X = \begin{Bmatrix} x_1 \\ \ldots \\ x_n \end{Bmatrix}}$ which minimizes *f(X)*

Subject to the constraints

***$g_j(X) \leq j = 1,2,\ldots, m$*** and

***$L_j(X) = 0, j = 1,2,\ldots, p$***

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## Statement of Optimization Problem

- *Where X is an n-dimensional vector - design vector*
- *f(X) - Objective Function*
- *$g_j(X)$ - Inequality Constraints*
- *$L_j(X)$ – Equality Constraints*
- *n- Number of Variables*
- *m- Number of inequality constraints*
- *p- Number equality constraints*

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## Statement of Optimization Problems (Contd.)

- Earlier discussed problem is known as **Constrained optimization Problem**

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## Definition of Terminology

- Design Vector
- Design Constraints
- Constraint Surface
- Objective Function

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## Design Vector

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## Design Vector

- Pre-assigned Parameters
- Design or Decision variables
- **Example: Gear-pair**
  - Face width – b
  - Number of teeth $T_1$ and $T_2$
  - Center distance d
  - Pressure Angle $\psi$
  - The tooth Profile
  - Material

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## Design Vector

- Pre-assigned Variables

  -Pressure Angle $\psi$

  -The tooth Profile

  -Material

- Design Vector

  $\boldsymbol{X = \{ x_1\ x_2\ x_3\} = \{ b, T_1, T_2\}}$

  *Design Space – N-dimensional*

  *Design point = { 1.0, 20, 40} – Possible Solution*

  *Design point = {1.0, -20, 40} – Impossible Solution*

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## Design Constraints

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## Design Constraints

- Design variables can not be chosen arbitrarily
- Design variables have to satisfy certain ***functional and other requirements***

- Types of Constraints

  Behavior or Functional Constraints

  Geometric or Side Constraints

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## Behavior/Functional Constraints

- They represent limitations on the behvaior or performance of the system
- Examples

  - Face width b can not be taken smaller than a certain value due to strength requirement

  - Ratio $T_1/T_2$ is dictated by speeds of the input and output of shafts $N_1$ and $N_2$.

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## Geometric/Side Constraints

- They represent physical limitations on the design variables like availability, fabricability and transportability
- Examples

  - $T_1$ and $T_2$ can not be real numbers

  - Upper and lower bounds on $T_1$ and $T_2$ due to manufacturing limitations.

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## Constraint Surface

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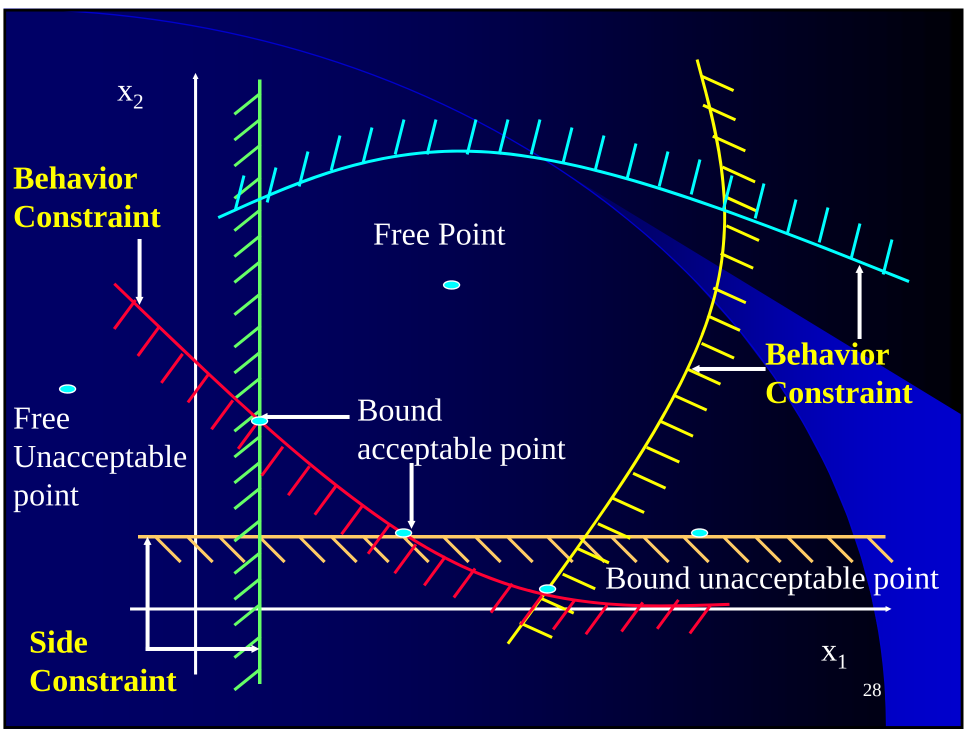

## Objective Function Surfaces

The locus of all points satisfying
*f(X) = c = Constant*
forms a hyper-surface in the design space

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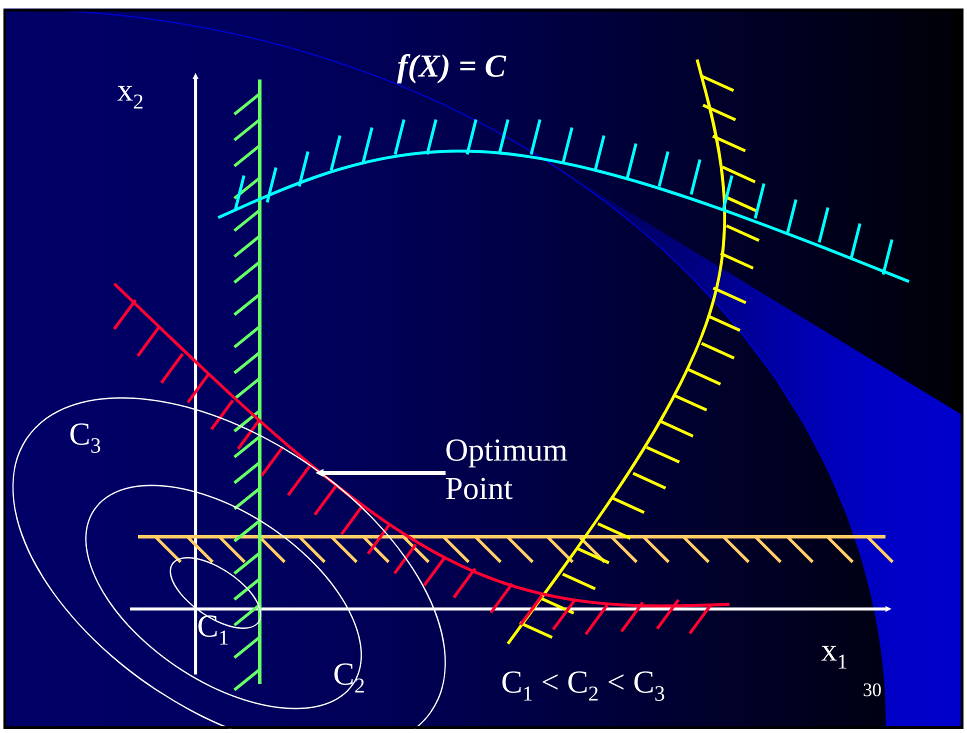

## Major Hurdle

- The number of design variables exceeds two or three, **the constraints and objective function surfaces become complex** even for visualization and the problem has to be solved purely as a **mathematical problem**.

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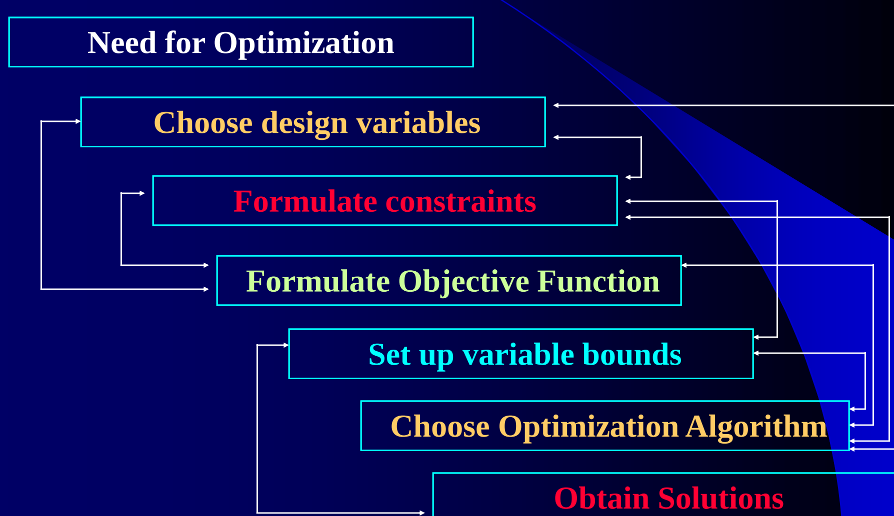
## Optimization Procedure

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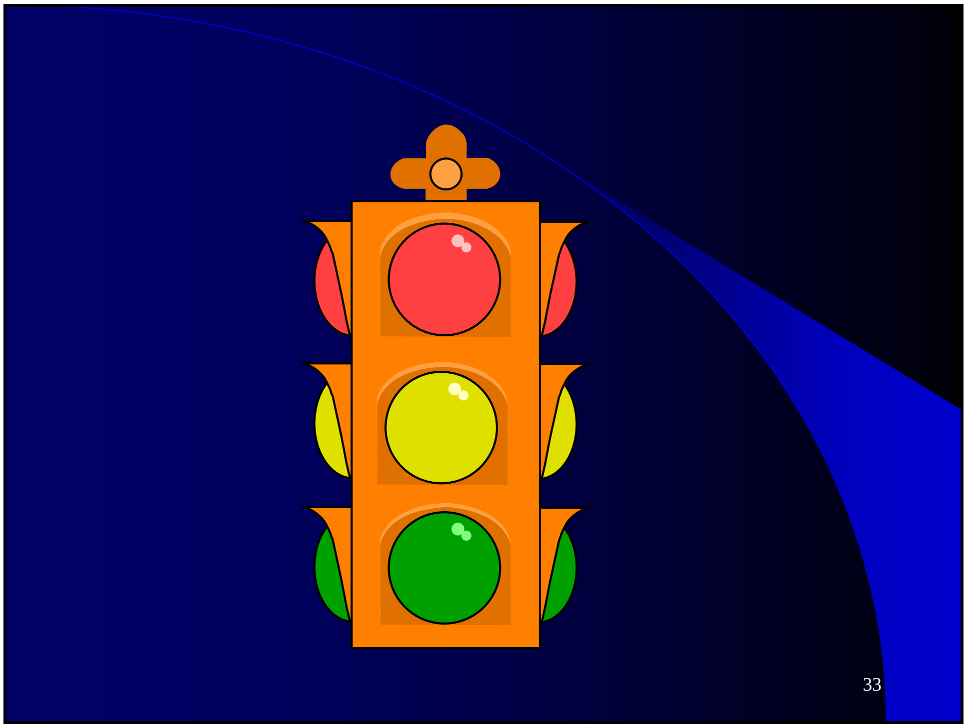
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