Lecture – 04
Introduction to soft computing

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GA Operators

Following are the GA operators in Genetic Algorithms.

1) Encoding
2) Convergence test
3) Mating pool
4) Fitness Evaluation
5) Crossover
6) Mutation
7) Inversion

Different Encoding Schemes

- **Different GA's**
  - Simple Genetic Algorithm (SGA)
  - Steady State Genetic Algorithm (SSGA)
  - Messy Genetic Algorithm (MGA)
- **Encoding Schemes**
  - Binary encoding
  - Real value encoding
  - Order encoding
  - Tree encoding

Different Encoding Schemes

Often, GAs are specified according to the encoding scheme it follows.

For example:

- Encoding Scheme
- Binary encoding – > Binary Coded GA or simply **Binary GA**
- Real value encoding – > Real Coded GA or simply **Real GA**
- Order encoding – > **Order GA** (also called as **Permuted GA**)
- Tree encoding

Encoding Schemes in GA

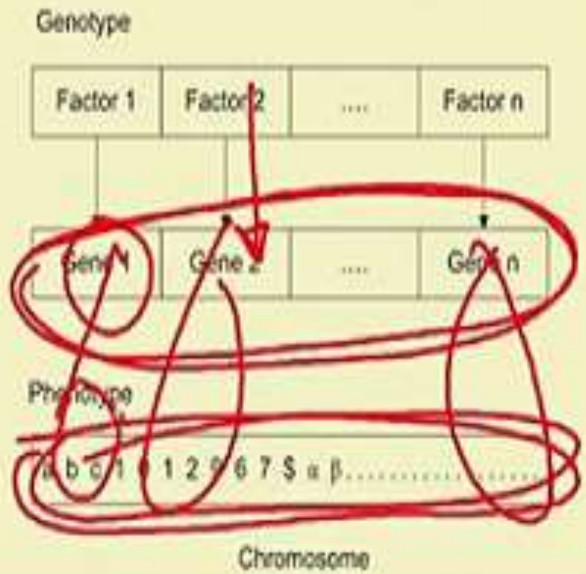
Genetic Algorithm uses metaphor consisting of two distinct elements :

1) Individual
2) Population

An individual is a single solution while a population is a set of individuals at an instant of searching process.

Individual Representation :Phenotype and Genotype

- An individual is defined by a chromosome. A chromosome stores genetic information (called phenotype) for an individual.
- Here, a chromosome is expressed in terms of factors defining a problem.



$f(x_1\ x_2\ x_3 \cdot\ x_n)$

0.3

Individual Representation :Phenotype and Genotype

Note :

- A gene is the GA's representation of a single factor (i.e. a design parameter), which has a domain of values (continuous, discontinuous, discrete etc.) symbol, numbering, etc.

- In GA, there is a mapping from genotype to phenotype. This eventually decides the performance (namely speed and accuracy) of the problem solving.

Encoding techniques

There are many ways of encoding:

1) **Binary encoding:** Representing a gene in terms of bits (0s and 1s).
2) **Real value encoding:** Representing a gene in terms of values or symbols or string.
3) **Permutation (or Order) encoding:** Representing a sequence of elements.
4) **Tree encoding:** Representing in the form of a tree of objects.

Binary Encoding

In this encoding scheme, a gene or chromosome is represented by a string (fixed or variable length) of binary bits (0's and 1's)

	x_1	x_2	x_3	x_4	
A :	0 1 1	0 0 1 0 1	0 1 0 1	0 1 1 1 1 0	Individual 1
	3	5	5	17	
B :	0 0 1	0 1 0 1 1	1 0 1 0	1 0 1 0 0 0	Individual 2

Example: 0-1 Knapsack problem

- There are n items, each item has its own cost (c_i) and weight (w_i).
- There is a knapsack of total capacity w.
- The problem is to take as much items as possible but not exceeding the capacity of the knapsack.

This is an optimization problem and can be better described as follows.

Maximize

$$\sum_i c_i \times w_i \times x_i$$

1

0

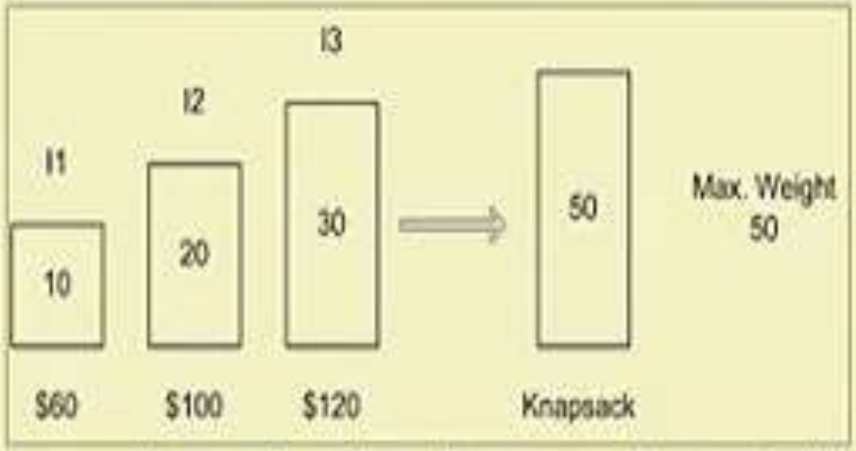
Subject to

$$\sum x_i \times w_i \leq W$$

where $x_i \in [0 \ldots \ldots \ldots 1]$

Example: 0-1 Knapsack problem

Consider the fallowing, an instance of the 0 – 1 Knapsack problem.



Brute force approach to solve the above can be stated as follows:

1) Select at least one item

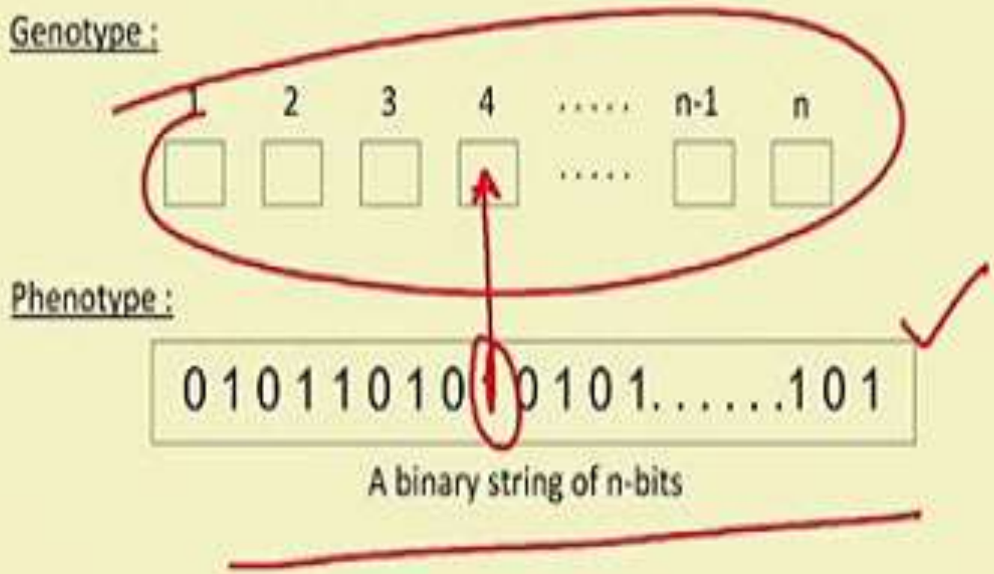
   [10], [20], [30], [10, 20], [10, 30], [20, 30], [10, 20, 30]

2) So, for n-items, are there are 2^{n-1} trials.
3) 0 – means item not included and 1 – means item included

   [100], [010], [011], [110], [101], [011], [111]

Example: 0-1 Knapsack problem

The encoding for the 0-1 Knapsack, problem, in general, for n items set would look as follows.



Few more examples

Example 1 :

Minimize :

$$f(x) = \frac{x^2}{2} + \frac{125}{x}$$

where $0 \le x \le 15$ and x is any discrete integer value.

Genotype :

x

1

Phenotype :

0 1 1 0 1

A binary string of 5-bits

4

2

Few more examples

Example 2 :

Maximize :

$$f(x,y) = x^3 - x^2y + xy^2 + y^3$$

subject to:

$$x + y \leq 10$$

and

$$1 \leq x \leq 10$$
$$-10 \leq y \leq 10$$

Genotype :

x	y

Phenotype :

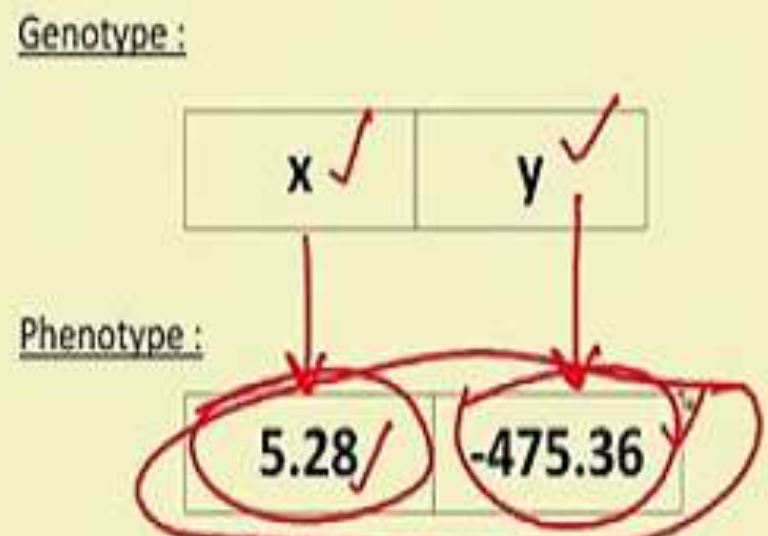
0 1 1 0 1	1 1 0 0 1

Two binary string of 5-bits each

13 25

Real value encoding

- The real-coded GA is most suitable for optimization in a continuous search space
- Uses the direct representations of the design parameters.
- Thus, avoids any intermediate encoding and decoding steps.



Real-value representation

Real value encoding with binary codes

Methodology: Step 1 [Deciding the precision]

For any continuous design variable x such that $X_L \leq x \leq X_U$, and if ϵ is the precision required, then string length n should be equal to

$$n = log_2\left(\frac{X_U - X_L}{\epsilon}\right)$$

Equivalently,

$$\epsilon = \left(\frac{X_U - X_L}{2^n}\right)$$

In general

$\epsilon = [0 \ldots \ldots 1]$. It is also called, Obtainable accuracy

Note:

If $\epsilon = 0.5$, then 4.05 or 4.49 $\equiv$ 4 and 4.50 or 4.99 $\equiv$ 4.5 and so on.

Real value encoding: Illustration 1

1) **Example 1:**

   $1 \leq x \leq 16, n = 6$. What is the accuracy?

$$\epsilon = \frac{16-1}{2^6} = \frac{15}{64} = 0.249 \approx 0.25$$

2) **Example 2:**

   What is the obtainable accuracy, for the binary representation for a variable X in the range $20.1 \leq X \leq 45.6$ with 8-bits?

3) **Example 3:**

   In the above case, what is the binary representation of $X = 34.3$

Real value encoding with binary codes

1) Methodology: Step 2[Obtaining the binary representation]

Once, we know the length of binary string for an obtainable accuracy (i.e. precision), then we can have the following mapping relation from a real value X to its binary equivalent decoded value X_B, which is given by

$$\boxed{X = X_L + \frac{X_U - X_L}{2^n - 1} \times X_B}$$

where X_B = Decoded value of a binary string,

n is the number of bits in the representation,

$X_L = 0\,0\,0\,0\,0\,0 \ldots \ldots \ldots 0$ and $X_U = 1\,1\,1\,1\,1\,1 \ldots \ldots \ldots 1$

are the decoded values of the binary representation of the lower and upper values of X.

Real value encoding: Illustration 2

Example:

Suppose, $X_L = 2$ and $X_U = 17$ are the two extreme decoded values of a variable x.

$n = 4$ is the number of binary bits in the representation for x.

$X_B = 10 (= 1\,0\,1\,0)$ is a decoded value for a given x.

What is the value of x =? and its binary representation??

Here, $x = 2 + \frac{17-2}{2^4-1} \times 10 = 12$

Binary representation of $x = 1\,1\,0\,0$