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A Review Paper on Different Encoding Schemes used in Genetic Algorithms

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Abstract— Genetic algorithms are adaptive methods which may be used to solve search and optimization problems like travelling salesman problem(TSP), Dejong's function, job scheduling problems. A genetic algorithm consist of following four operation namely: Initialization , selection, Reproduction and replacement. Generation of initial population by using suitable encoding scheme is called Initialization. Encoding is main key of success of genetic algorithm. Encoding is the way to represent the solution. This paper presents different encoding schemes like binary encoding scheme, permutation encoding scheme, Value encoding schemes, octal encoding schemes used in genetic algorithm.

Keywords— Crossover, Encoding scheme, Genetic Algorithm(GA), mutation.

I. INTRODUCTION

Genetic algorithm: Genetic algorithm[1] was developed by john Holland in early of 1970's. It is a search heuristic that mimics the process of natural selection. This heuristic is used to generate useful solutions to optimization and search problems. A genetic algorithm (GA) is a method for solving both constrained and unconstrained optimization problems based on a natural selection process that mimics biological evolution. The algorithm repeatedly modifies a population of individual solutions. At each step, the genetic algorithm randomly selects individuals from the current population and uses them as parents to produce the children for the next generation. Genetic Algorithm works on two types of spaces alternatively, coding space (genotype) and solution space (phenotype). The phenotype describes the outward appearance of an individual. A transformation exists between genotype[2] and phenotype, also called mapping, which uses the genotypic information to construct the phenotype [4]. A chromosome refers to a string of certain length where all the genetic information of an individual is stored. Each chromosome consists of many alleles. Alleles are the smallest information units in a chromosome.

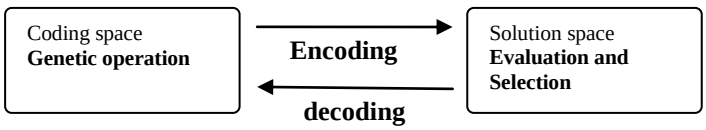


Fig 1: Encoding – Decoding method

Encoding scheme:- It is a process of representation of individual genes. The process of representation can be performed by using bits, numbers, trees, arrays and list or any other objects.[6]
Depending on the structure of encoding, they can be classified into 1-dimensional and 2-dimensional. Binary, Octal, Hexadecimal, permutation and value encodings are 1-dimensional and Tree encoding is 2-dimensional [3]. According to Goldberg, the fitness function for a specific encoding scheme depends on two factors - value and order.

II. Classification of encoding on fitness evaluation factor:

- Encoding schemes [5] where fitness depends on *order* only: f(o) e.g. Permutation encoding.
- Encoding schemes where fitness depends on *value only* : f(v,o) e.g. Binary encoding.

1. Binary encoding: Binary encoding is the most common representation of chromosomes in genetic algorithm. In this encoding the chromosomes are represented by the binary string as {0,1}[6].

For example:

Chromosome 1:	**101101100111**
Chromosome 2:	**100011010110**

Fig.2: Binary Encoding

In this encoding scheme each bit represent the characteristics of solution. There are number of crossover schemes which are suitable for the binary encoding. These schemes are One point crossover, N point crossover and Uniform crossover. The mutation operator which is suitable for the binary encoding is flip bit. In the flip bit mutation, the bits are changes from 0's to 1's and vice versa.

Example: knapsack problem is the example of binary encoding.

1.1 Crossover schemes:

- **One point crossover**: In this crossover scheme one crossover point is selected from the binary string. The beginning bits of string are copied from the first parent and rest bits from the second parent of the crossover point.

For example:

Parent 1:	**11001011**
Parent 2:	**11011111**

11001011+11011**111** = 11001111

In this example the crossover point is 5^{th} bit of string.

- **Two point crossover:** In this crossover scheme two points are selected from the binary string. In this from beginning of chromosome to the first crossover point is copied from one parent, the part from the first to the second crossover point is copied from the second parent and the rest is copied from the first parent.

For example:

Parent 1:	**11001011**
Parent 2:	**11011111**

11001**011** + 11**011**11 = **11011111**

- **Uniform crossover** – In this crossover scheme the bits are randomly copied from the first or from the second parent.

For example:

Parent 1:	**11001011**
Parent 2:	**11011101**

1**10**01**011** + **1**10**111**01 = 11011111

- **Arithmetic crossover**: In this crossover scheme some arithmetic operations is performed to make a new offspring.

For example:

Parent 1:	**11001011**
Parent 2:	**11011101**

11001011 + 11011111 = 11001001 (AND)

1.2 Mutation schemes:

- **Flip bit mutation:** In this mutation scheme selected bits are inverted. This is also called as bit inversion.

For example:

Parent 1: **11001011**

1**10**01011 ⟶ 1**01**01011

2. Octal encoding: In this encoding scheme the string of chromosome is represented by the octal numbers(0-7)[6].

For example:

Chromosome 1:	**05694725**
Chromosome 2:	**32652341**

Fig. 3: Octal Encoding

3. Hexadecimal encoding: In this encoding scheme the string of chromosome is represented by the hexadecimal numbers (0-9, A-F)[6].

For example:

Chromosome 1:	**9C8F**
Chromosome 2:	**A7B9**

Fig.4: Hexadecimal Encoding

4. **Permutation encoding:** This encoding scheme is used in ordering problems such as travelling salesman problem. In this the string of numbers are represent the cities visited by salesman. In this encoding every chromosome is a string of numbers that represent a position in a sequence
   For example:

Chromosome 1:	**126548269**
Chromosome 2:	**756489213**

Fig.5: Permutation encoding

This encoding is only useful for the problems that have a specific order. The crossover operators that performed on permutation encoding are Partially matched crossover (PMX), Cycle crossover (OCX) and Order crossover (OX). The mutation operator that performed on permutation encoding is Inversion [5].

Example: Travelling salesman problem(TSP) is the example of permutation encoding.

4.1 Crossover scheme:

- **Partially matched crossover (PMX):** In this crossover two strings are aligned and two crossover points are selected at random from the strings. These points gives a matching selection which is used to affect a cross position by position exchange operation.
  Consider two strings:

Parent 1 : 4 8 7| 3 6 5| 1 10 9 2
Parent 2 : 3 1 4| 2 7 9| 10 8 6 5
In this (3,2),(6,7),(5,9) are the exchange places by mapping parent 1 to 2 and from 2 to 1 exchange places are (2,3),(7,6),(9,5). Now the offspring produced is as:
Child 1 : 4 8 6| 2 7 9| 1 10 5 3
Child 2 : 2 1 4| 3 6 5| 10 8 7 9

- **Order crossover:** It is similar to PMX. As we select two crossover points to exchange order in PMX, Order crossover applies sliding motion for filling the left holes by transferring the mapped positions.

Consider two strings:
Parent 1 : 4 8 7| 3 6 5| 1 10 9 2
Parent 2 : 3 1 4| 2 7 9| 10 8 6 5

On mapping parent 2 with parent1, the places 3,6,5 are left with holes.
Child 2: H 1 4 2 7 9 10 8 H H
Now, these holes are filled with sliding motion that start from the second crossover point.
Child 2: 2 7 9 H H H 10 8 1 4
Similarly the holes are filled from the parent1.
Therefore child 1 shows as:
Child 1: 3 6 5| 2 7 9| 1 10 4 8
&
Child 2: 2 7 9| 3 6 5| 10 8 1 4

- **Cycle crossover**: It is different from other two crossovers. It performs recombination under the constraint that each gene comes from the parent or the other.

4.2 Mutation scheme:

- **Order changing** –In this mutation two numbers are selected and exchanged.
  For example:
  (1 2 3 4 5 6 8 9 7) => (1 8 3 4 5 6 2 9 7)

5. **Value encoding**: In **value encoding**, every chromosome is a string of some values[6]. Values can be anything connected to problem, form numbers, real numbers or characters to some complicated objects. Value Encoding can be used in neural networks. This encoding is generally use in finding weights for neural network. Chromosome's value represents corresponding weights for inputs.

For example:

Chromosome 1:	**1.2324 5.3243 0.4556 2.3293**
Chromosome 2:	**ABDJEIFJDHDIERJFDLDFL**
Chromosome 3:	**(back), (back), (right), (forward)**

Fig.6: Value encoding

Value encoding is very good for some special problems. On the other hand, for this encoding is often necessary to develop some new crossover and mutation specific for the problem.

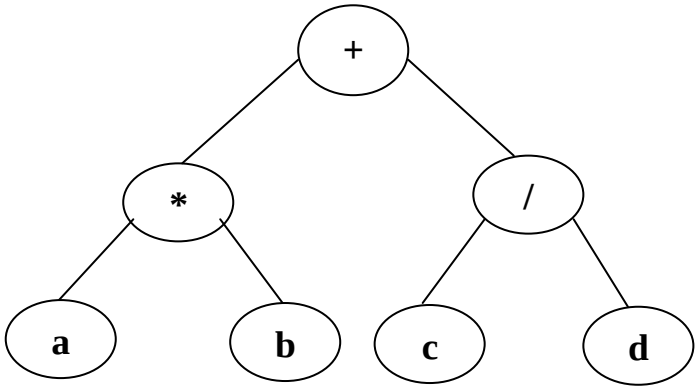
Example: Neural network is the example of value encoding. To find the weights in neural network value encoding is used.

6. **Tree Encoding**: Tree encoding is used mainly for evolving programs or expressions, for **genetic programming**. In this scheme every chromosome is a tree of some objects, such as functions or commands in programming language.

For example:

Chromosome 1:	**(+(*ab)/(cd))**
Chromosome 2:	**Do until step stair**

Chromosome 1:



Chromosome 2:

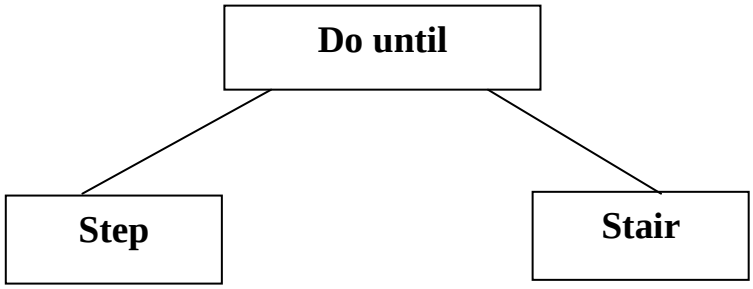


Fig 7: Tree representation of chromosomes

Example: Finding the function from their given values.

6.1 Tree crossover: - In this crossover one crossover point is selected by both parents and then the parents are divided in that point and exchange part below crossover point to produce new offspring. In this every chromosome is a tree of some other objects.[6]

For example:

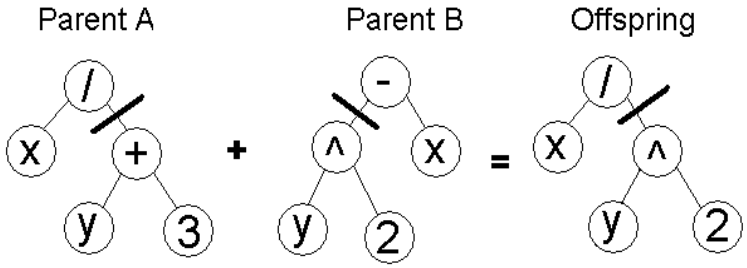


Fig 8: crossover in tree encoding.

III. Conclusions

The paper has discuss the different encoding schemes used in genetic algorithm. It was found that encoding schemes used in genetic algorithm is depend upon type of problem. If problem is like TSP then permutation encoding schemes is used and if problem is like knapsack problem then binary encoding schemes is used.

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