ISSN:0975-9646

Nitasha Soni et al, / (IJCSIT) International Journal of Computer Science and Information Technologies, Vol. 5 (6) , 2014, 7235-7238

Study of Various Crossover Operators in Genetic Algorithms

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***Abstract*— Genetic Algorithms are the population based search and optimization technique that mimic the process of natural evolution. Performance of genetic algorithms mainly depends on type of genetic operators – Selection, Crossover, Mutation and Replacement used in it. Different crossover and mutation operators exist to solve the problem that involves large population size. Example of such a problem is travelling sales man problem, which is having a large set of solution. In this paper we will discuss different crossover operators that help in solving the problem.**

Keywords — Genetic Algorithm; Mutation; crossover; Selection; travelling salesman problem.

I. INTRODUCTION:

Evolutionary algorithms are the ones that follow the Darwin concept of "Survival of the fittest" mainly used for optimization problems for more than four decades [1]. As we all know that evolutionary algorithms are the example of heuristic search algorithms which do not guarantee always to provide the exact optimal solutions, but they will definitely help to find better optimal solutions as compared to other one within less amount of time. This principle is similar to some kind of exam among individuals for very limited resources present in nature that results in the fittest individuals rules over the weaker ones. A number of of the evolutionary algorithms are Genetic algorithms by nature, by nature Genetic programming, by nature Evolutionary programming and Evolutionary Strategies etc. Genetic algorithms are by nature adaptive optimization algorithms that mimic the process of natural selection and genetics [2]. The Exploitation and exploration techniques are responsible for the performance of genetic algorithms. Exploitation means to use the already existing information to find out the better solution and Exploration is to investigate new and unknown solution in exploration space. The authority of genetic algorithms comes from their ability to combine both exploration and exploitation in an optimal way [3]. Biological genetics model is the role model of genetic algorithm. A generic genetic algorithm consists of following operations namely: Initialization, Selection, Reproduction and Replacement. Initialization refers to creation of initial population by using some suitable encoding scheme. Selection operator chooses the individuals arbitrarily or according to their fitness. Crossover and mutation are used to maintain balance between exploitation and exploration. During replacement, the old individuals are replaced by new offspring's [4]. Some of the main operators that are mostly used in genetic algorithms are selection, crossover and mutation. By definition, crossover is a typical process that happens between a pair of homologous chromosomes. Two chromosomes are physically aligned and break over the one or more location so as to exchange their fragments. In genetic algorithms, chromosomes represented as linear strings of symbols [5].

It is very important that in order to improve the functionality of genetic algorithm problem specific crossover must be used. After reproduction or we say that after selection process, the population is consist with better individuals. Reproduction or selection makes same individual but they are better individual as compared to old one. The main feature of genetic algorithms is to combine both exploration and exploitation in an optimal way. In reality, the population size is known to us that affect the performance of genetic algorithm and leads to the problem of genetic drift that occurs mostly in case of multimodal search space. By introducing a local search method within the genetic operators can produce new genes than can overcome the problem of genetic drift and accelerate the search towards global optima [6]. We can combine a genetic algorithm and a local search method and that is called as hybrid genetic algorithm/mimetic algorithm. Some crossover operator are used for exploitation while other for exploration. Our main focus of this paper is to study different types of crossover operators

II. TRAVELLING SALESMAN PROBLEM:

The Travelling Salesman Problem (TSP) is one of the most widely used and well studied combinatorial optimization problems. The first statement of the Travelling Salesman Problem (TSP) was made in 1930 by the Viennese mathematician Karl Menger. Its statement is very simple, and that's why it becomes one of the most challenging and popular problems in the felid of Operational Research. A number of articles and research papers are been written and published on the TSP. The most common practical interpretation of the TSP is that of a salesman seeking the shortest tour through n clients or cities. The Travelling Salesman Problem is one of the best known NP-hard problems, which means that there is no exact algorithm to solve it in polynomial time. The least likely time to obtain optimal solution is exponential [7]. Our main objective is to find the path of the shortest length or with the minimum cost. It is a problem where starting and finishing points are same and we have to return to the point after having visited each other vertex only once. The most popular practical applications of TSP are not only regular distribution of goods or resources, finding of the shortest of costumer

servicing route, planning bus lines, vehicle routing, computer wiring, machine sequencing and scheduling, frequency assignment in communication networks
etc., but also in the areas that have nothing to do with travel routes [7].
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III. VARIOUS APPROACHES USED FOR SOLVING TSP

In 1997, Rong Yang introduce several knowledge-augmented genetic operators which guide the genetic algorithm more directly towards better quality of the population but are not trapped in local optima prematurely. The algorithm use a greedy crossover operator and two advanced mutation operations based on the 2-opt and 3-opt heuristics [8].In 2001, Chiung Moon introduces the concept of topological sort (TS), which is defined as an ordering of vertices in a directed graph. Also, a new crossover operation is introduced for the proposed GA [9].In 2004, new knowledge based multiple inversion operators and a neighbourhood swapping operator is proposed by Shubhra Sankar Ray [10].In 2005, Lawrence V. Snyder presents a heuristic to solve the generalized travelling salesman problem. The procedure incorporates a local tour improvement heuristic into a random-key genetic algorithm. The algorithm worked quite well when tested on a set of 41 standard problems with known optimal objective values [11]. In 2005, Milena Karova introduces the solution, which includes a genetic algorithm implementation in order to give a maximal approximation of the problem, modifying the obtained solution with genetic operators [12].In 2006, Plamenka Borovska investigates the efficiency of the parallel computation of the travelling salesman problem using the genetic approach on a slack multicomputer cluster [13].In 2007, A two-level genetic algorithm (TLGA) was developed for the problem, which special treatment neither intra-cluster paths nor inter-cluster paths, thus realized integrated evolutionary optimization for both levels of the CTSP [14].In 2007, A novel particle swarm optimization (PSO)-based algorithm for the travelling salesman problem (TSP) is presented, and is compared with the existing algorithms for solving TSP using swarm intelligence [15].In 2008, A software system is proposed to determine the optimum route for a Travelling Salesman Problem using Genetic Algorithm technique [16].In 2009, S.N. Sivanandampresents two approaches i.e Genetic Algorithms and Particleswarm optimisation to find solution to a given objective function employing different procedures and computational techniques; as a result their performance can be evaluated and compared [17].

IV. GA METHODOLOGY

Genetic algorithm is a fraction of evolutionary computing, which is a fast mounting part of artificial intelligence. Genetic algorithm is motivated by Darwin's theory about evolution. It is not too hard to program or realize, since they are biological based.

V. TYPES OF CROSSOVER OPERATORS

1) Single Point Crossover-

Single point crossover is the most popular crossover and it is widely used. A crossover site is aimlessly selected along the length of the mated strings and bits next to the cross-sites are exchanged. If suitable site is chosen, better children can be obtain by combining good quality parents else it harshly hamper string quality. In single point crossover the head and tail of one chromosome break up and if both head and tail have good genetic material then none of the offspring will get the both good features directly.

2) N-Point Crossover-

The N-point crossover was first implemented by De Jong in 1975 [18]. It has many cross over sites but rule used is same as we used in single point crossover. In 2-point crossover significance of crossover sites is 2. Adding more and more crossover sites effect the disruptions of building blocks that sometimes reduce the performance of genetic algorithm. But it allows the head and tail section of a chromosome to be accepted together in the offspring.

3) Uniform Crossover-

Uniform crossover do not fragments the chromosomes for recombination. Each gene in offspring is created by copying it from the parent chosen according to the corresponding bit in the binary crossover mask of same length as the length of the parent chromosomes [17]. If the bit in crossover mask is 1, then the resultant gene is copied from the first parent and if the bit in crossover mask is 0, then the resultant gene is copied from the second parent. A new crossover mask is generated arbitrarily for each pair of parent chromosomes. The quantity of crossover point is not fixed initially. So, the offspring have a mixture of genes from both the parents.

4) Three Parent Crossover-

In this crossover, three parents are chosen arbitrarily. Each gene of the 1st parent is compared with the equivalent gene of the 2nd parent. If both genes are similar, the gene is occupied for offspring or else the equivalent gene from the 3rd parent is taken for the offspring. It is mostly used in case of binary encoded chromosomes.

5) Arithmetic Crossover-

Arithmetic crossover is used in case of real-value encoding. Arithmetic crossover operator linearly combines the two parent chromosomes [17]. Two chromosomes are particular randomly for crossover and create two offspring's which are linear mixture of their parents.

6) Partially mapped Crossover-

Partially Matched or Mapped Crossover (PMX) is the most frequently used crossover operator. It was proposed by Goldberg and Lingle [19] for Travelling Salesman Problem. In Partially Matched Crossover, two chromosomes are associated and two crossover sites are chosen arbitrarily. The fraction of chromosomes between the two crossover points gives a corresponding selection that undergoes the crossover process through position-by-position exchange operations [2, 17]. PMX tends to respect the absolute positions.

7) Order Crossover (OX)-

It was proposed by Davis and also used for chromosomes with permutation encoding [20]. The process starts in a way similar to PMX by choosing two crossover points. But in its place of using point-by-point exchanges as in case of PMX, order crossover applies sliding motion to fill up the left out holes by sending the mapped positions. It copies the portion of permutation elements between the crossover points from the cut string directly to the offspring, insertion them in the same absolute position [2, 17]. OX tends to respect the relative positions.

8) Cycle Crossover (CX)-

this crossover is used for chromosomes with permutation encoding. During recombination in cyclic crossover there is a limitation that each gene either comes from the one parent or the other [21]. The fundamental model at the back cycle crossover is that each allele comes from one parent jointly with its position. To construct a cycle of alleles from parent1 we have to start with the first allele of parent1. Then look at the allele at the equal position in parent2 and go to the position with the same allele in Parent1.insert this allele to the cycle and do again above step until you reach your destination at the first allele of parent1. Put the alleles of the cycle in the first child on the positions they have in the first parent and the remaining alleles of first child come from the second parent along with their position. Produce next cycle from parent2.

VI. Solving TSP Using Genetic Algorithm

A genetic algorithm is popular to find a solution of a problem in much less time. Even though it might not find the most excellent solution of the problem but it can help in finding a near ideal solution for a 100 city tour in less than a minute. The following are some fundamental steps of our proposed work.

- **Encoding:** permutation encoding is most popular way to solve the TSP. We characterize cities with an integer value, and after that we initialize the population.
- **Distance matrix:** distance matrix is an representation of N*N matrix of point to point distances.
- **Selection based on fitness function:** the fitness function will be total expenditure of the visit represented by each chromosome. The smaller the sum, the fitter the solution represented by that chromosome[22]
- Generating arbitrary numbers equal to population size.
- separating arbitrary numbers into interval of two
- According to string of arbitrary numbers choosing routes from population size.
- top of two routes will be chosen using tournament selection to relate Mutation.
- Next generation of population size will be produced.
- Process will go through predefined iterations.
- After the final iteration the smallest number of distance size will be displayed as result.

VII. Conclusion

In this paper, we have discussed eight types of mutations strategy in the genetic algorithm procedure to create new and better generations. As we learnt that genetic algorithms appear to be a good solution for TSP, however it very much depends on the technique the difficulty is encoded and which crossover and mutation methods are used. So our labours will decide which mutation operator will always gives end result to undertake most of the real life applications of travelling salesman problem.

VIII. Future Scope

It appears that major dilemma with the genetic algorithm for TSP is that to preserve the formation from the parent's chromosomes and still finish up with a permissible tour in the child chromosomes. Possibly a improved crossover or mutation routine that remain structure from parent chromosome would give a far better clarification than we have previously establish for some TSP. As a potential work we want to prolong the same process with different other crossover and mutation operator to give an improved solution to a TSP.

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