Study of Various Mutation Operators in Genetic Algorithms

[1]Nitasha Soni, Dr [2]Tapas Kumar

Lingaya's University, Faridabad

Abstract— **Genetic Algorithms are the population based search and optimization technique that mimic the process of natural evolution. 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 mutation operators that help in solving the problem.**

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

I. INTRODUCTION:

The Travelling Salesman Problem (TSP) is one of the most commonly studied and used combinatorial optimization problems. Its statement is extremely simple, but it remains one of the most challenging problems in Operational Research. Large numbers of articles have been written on this problem. The book edited by Lawler et al. (1985) provides an insightful and comprehensive survey of all major research results until that date [3]. The purpose of this survey paper is to put lime light on solving the TSP using genetic algorithm. The goal is to find the shortest tour that visits each city in a given list exactly once and then returns to the starting city. In contrast to its simple definition, solving the TSP is difficult since it is an NP-complete problem [4]. TSP is solved very easily when there is less number of cities, but as the number of cities increases it is very difficult to solve, as large amount of time is required. The most common place where TSP is used very effectively is military and traffic. We use genetic algorithm to solve TSP because of its robustness and flexibility that will help in solving problem in optimal time .Apart from its theoretical approach, the TSP has many applications. Some typical and important applications of TSP include vehicle routing, computer wiring, cutting wallpaper and job sequencing. The main application in statistics is combinatorial data analysis, e.g., reordering rows and columns of data matrices or identifying clusters. [5]

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]. These are the heuristic search that not always guarantee to provide best solution but it can provide a better solution in an optimal time. Some of them are Genetic algorithms, Evolutionary Strategies etc. Genetic algorithms are adaptive optimization algorithms that mimic the process of natural selection and genetics [2]. A genetic algorithm consists of some very popular operations like Initialization, Selection, Reproduction and Replacement. Initialization means generation of initial population by using some suitable encoding. Selection operator means selection of the individuals randomly or according to their fitness that depends on the nature of the problem also. Crossover and mutation are the two very important and commonly used operators to maintain diversity in the population. And during replacement, the old individuals are replaced by new offspring's to generate the new generations. The whole cycle stops when the optimal result is achieved.

II. TRAVELLING SALESMAN PROBLEM:

The idea of TSP is to find a tour of a given numbers of cities, visiting each city exactly once and returning to the starting city where the length of the tour is minimized. The first instance of the travelling salesman problem was in 1759 whose problem was to move a knight to every posituon on the chess board exactly once[6]. The main idea is to cover as many location as possible without visiting any location twice.

The TSP can be stated mathematically as follows:

Given a weighted graph G=(V,E) where the weight between nodes is non negative number and we have to find the tour of all nodes or cities that has a minimum total cost. The best or optimal solution of solving Travelling salesman problem is to evaluate all possible tours and search for the tour which is having minimum cost. Foe example if we are having n cities then number of possible path is n!. If n is small we can solve the pboblem in a limited time. For example if we have 5 cities then total 5! Path exist to evaluate the minimum cost, it can be done in small amount of time but if n is large it become impossible to find the cost of every tour in polynomial time. However TSP does not find application in many fields. Indeed many direct application of TSP bring life to the research area and help to direct future work like Genome Sequencing, Starlight Interferometer Program, Scan Chain Optimization, DNA Universal Strings, Whizzkids 96 Vehicle Routing, Touring Airports and Designing Sonet Rings etc.

There is one more catergory of TSP i.e. multiple travelling sales man problem(m TSP), which consists of determining a set of routes from salesmen who all start from and turn back to a home city. In multiple travel sales men problem we have m salesmen located at single deport point. The remaining cities to be visited are called intermediate nodes. Then the m TSP consists of finding tours for all m salesmen, who all start and end at the deport, such that each intermediate node is visited exactly once and the total cost of visiting all nodes is minimized. The cost metric can be define in term of distance, time, etc. Multiple travelling salesmen problem also have many application like Printing

press scheduling problem, School bus routing problem, Crew scheduling problem and Design of global navigation satellite syatem surveying networks etc.

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 applies a greedy crossover and two advanced mutation operations based on the 2-opt and 3-opt heuristics [7].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 developed for the proposed GA [8].In 2004, new knowledge based multiple inversion operators and a neighbourhood swapping operator is proposed by Shubhra Sankar Ray [9].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 performed quite well when tested on a set of 41 standard problems with known optimal objective values [10]. In 2005, Milena Karova introduces the solution, which includes a genetic algorithm implementation in order to give a maximal approximation of the problem, modifying a generated solution with genetic operators [11].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 [12].In 2007, A two-level genetic algorithm (TLGA) was developed for the problem, which favours neither intra-cluster paths nor inter-cluster paths, thus realized integrated evolutionary optimization for both levels of the CTSP [13].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 [14].In 2008, A software system is proposed to determine the optimum route for a Travelling Salesman Problem using Genetic Algorithm technique [6].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 [15].

IV. GA METHODOLOGY

Genetic algorithm is a heuristic search that is based on the process of natural evolution [16]. Genetic algorithm belongs to the larger class of evolutionary algorithms, which generate solution to optimization problems using techniques inspired by natural evolution such as inheritance, mutation, selection and crossover.

IV. TYPES OF MUTATIONS

Types of Mutation:
1) **Insert Mutation-** It is used in Permutation encoding. First of all, pick two allele values at random. Then move the second allele to follow the first, shifting the rest along to accommodate. Note that this preserves most of the order and the adjacency information [16].
2) **Inversion Mutation-** Inversion mutation is used for chromosomes with permutation encoding. In order to perform inversion, pick two alleles at random and then invert the substring between them [16]. It preserves most adjacency information and only breaks two links but it leads to the disruption of order information.
3) **Scramble Mutation-** Scramble mutation is also used with permutation encoded chromosome. In this mutation, one has to pick a subset of genes at random and then randomly rearrange the alleles in those positions. Subset does not have to be contiguous.
4) **Swap Mutation-** It is also used in Permutation encoding. To perform swap mutation select two alleles at random and swap their positions. It preserves most of the adjacency information but links broken disrupts order more [16].
5) **Flip Mutation**- Based on a generated mutation chromosome, flipping of a bit involves changing 0 to 1 and 1 to 0. A parent is considered and a mutation chromosome is randomly generated [16]. For a 1 in mutation chromosome, the corresponding bit in parent chromosome is flipped (0 to 1 and 1 to 0) and child chromosome is produced. It is commonly used in binary encoding.
6) **Interchanging Mutation**- Two random positions of the string are chosen and the bits corresponding to those positions are interchanged [16].
7) **Reversing Mutation**- In case of reversing mutation applied for binary encoded chromosome, random position is chosen and the bits next to that position are reversed and child chromosome is produced [16].
8) **Uniform Mutation-** The Mutation operator changes the value of chosen gene with uniform random value selected between the user specified upper and lower bound for that gene [16]. It is used in case of real and integer representation.
9) **Creep Mutation-** In creep mutation, a random gene is selected and its value is changed with a random value between lower and upper bound. It is used in case of real representation [16].

V. SOLVING TSP USING GENETIC ALGORITHM

A genetic algorithm is used to find a solution in much less time. Although it might not find the best solution but it can find a near perfect solution for a 100 city tour in less than a minute. The following are some basic steps of our proposed work.

- **Encoding:** permutation encoding will be used to solve TSP. We represent cities with an integer value, and after that we initialize the population.
- **Distance matrix:** distance matrix is an N*N matrix of point to point distances.
- **Selection based on fitness function:** the fitness function will be total cost of the tour represented by each chromosome. The lesser the sum, the fitter the solution represented by that chromosome.[17]

- Generating random numbers equal to population size.
- Dividing random numbers into interval of two
- According to sequence of random numbers selecting routes from population size.
- Best of two routes will be chosen using tournament selection to apply Mutation.
- Next generation of population size will be generated.
- Process will undergo predefined iterations.
- After the final iteration the smallest distance size will be displayed as result.

VI. CONCLUSION

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

VII. FUTURE SCOPE

It seems that biggest problem with the genetic algorithm for TSP is that to maintain the structure from the parent's chromosomes and still end up with a legal tour in the child chromosomes. Perhaps a better crossover or mutation routine that remain structure from parent chromosome would give a better solution than we have already found for some TSP. As a future work we want to continue the same procedure different other crossover and mutation operator to give a better solution to a TSP.

REFERENCES

[1]   J. Holland, Adaptation in natural and artificial systems, University of Michigan Press, Ann Arbor, 1975.
[2]   D.E. Goldberg, Genetic algorithms in search, optimisation, and machine learning, Addison Wesley Longman, Inc., ISBN 0-201-15767-5, 1989.
[3]   Gilbert Laporte , The Traveling Salesman Problem: An overview of exact and approximate algorithms, Centre de recherche sur les transports, Universit~ de Montr&l, C.P. 6128, Station A, Montreal, Canada H3C M7
[4]   E. L. Lawler, J. K. Lenstra, A. H. G. RinnooyKan, and D. B. Shmoys (1985), The Traveling Salesman Problem, John Wiley & Sons, Chichester.
[5]   Adewole Philip, A Genetic Algorithm for Solving Travelling Salesman Problem, (IJACSA) International Journal of Advanced Computer Science and Applications, Vol. 2, No.1, January 2011
[6]   Emanuel Falkenauer. Genetic algorithm and grouping problem. John Wiely and sons, 1998
[7]   Rong Yang, "Solving Large Travelling Salesman Problems with Small Populations". IEEE 1997.
[8]   Chiung Moon, Jongsoo Kim, GyunghyunChoi ,YoonhoSeo," An efficient genetic algorithm for the traveling salesman problem with precedence constraints", European Journal of Operational Research 140 (2002) 606–617, accepted 28 February 2001.
[9]   ShubhraSankar Ray, Sanghamitra Bandyopadhyay and Sankar K. Pal," New Operators of Genetic Algorithms for Traveling Salesman Problem", 2004 IEEE.
[10]   Lawrence V. Snyder a,*, Mark S. Daskin ," A random-key genetic algorithm for the generalized traveling salesman problem", European Journal of Operational Research 174 (2006) 38–53, 2005.
[11]   Milena Karova, VassilSmarkov ,StoyanPenev," Genetic operators crossover and mutation in solving the TSP problem", International Conference on Computer Systems and Technologies - CompSysTech' 2005.
[12]   Plamenka Borovska," Solving the Travelling Salesman Problem in Parallel by Genetic Algorithm on Multicomputer Cluster", International Conference on Computer Systems and Technologies - CompSysTech'06
[13]   DING Chao, CHENG Ye , HE Miao," Two-Level Genetic Algorithm for Clustered Traveling Salesman Problem with Application in Large-Scale TSPs", TSINGHUA SCIENCE AND TECHNOLOGY ISSN 1007-0214 15/20 pp459-465 Volume 12, Number 4, August 2007
[14]   X.H. Shi , Y.C. Liang, H.P. Lee, C. Lu, Q.X. Wang," Particle swarm optimization-based algorithms for TSP and generalized TSP", Information Processing Letters 103 (2007) 169–176,2007.
[15]   S.N. Sivanandam,S.N.Deepa,"A Comparative Study Using Genetic Algorithm and Particle Swarm Optimization for Lower Order System Modelling," International Journal of the Computer, the Internet and Management Vol. 17. No.3 (September - December, 2009) pp 1 -10.
[16]   S.N. Sivanandam and S. N. Deepa., Introduction to Genetic Algorithms, Springer, ISBN 9783540731894, 2007
[17]   Fanchen Su et al,-New Crossover Operator of Genetic algorithm for the TSPI, International joint conference on computational science and optimization, IEEE, 2009 pp 666-669
Links
[16]   http://www.darwins-theory-of-evolution.com/