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A Comparative Analysis of Selection Schemes of Genetic Algorithm to Find an Optimum and Reliable Route in Wired Networks

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Abstract

The single source shortest path problem is one of the most studied problems in algorithmic graph theory. Single Source Shortest Path is the problem in which we have to find shortest paths from a source vertex v to all other vertices in the graph. And we incorporate this problem in the wired network for finding the reliable route between the nodes of wired network. A number of algorithms have been proposed for this problem. Most of the algorithms for this problem have evolved around the Dijkstra's algorithm. This paper gives the description of a genetic algorithm with best suitable selection method that can be used to find an optimal and reliable route between nodes of a wired network so that the average end to end time of routing packets from one node to the other node can be minimized. In this paper, we are going to do comparative analysis of the selection methods of Genetic Algorithm to solve this problem which is an optimization algorithm based on evolutionary ideas of natural selection and genetics.

Keywords: *Single Source Shortest Path Problem, Genetic Algorithm, Selection mechanisms.*

1. Introduction

With the popularity of the computer and the development of the geographic information science, GIS has been increasingly extensive and in-depth applications for its powerful functions. As one of the most important functions, network analysis has played an important role in lots of fields, such as electric navigation, traffic tourism, urban planning and electricity, communications, and other various pipe network designs and so on. The key problem about network analysis is his shortest path analysis. The shortest path analysis not only refers to the shortest distance in general geographic sense, but also extends to other measurements, such as time, cost, and the capacity of the line.

In this paper we consider the network topology as a graph of ‘n’ number of nodes and ‘e’ number of edges and each edge is assign a weight which is related to the delay, throughput, routing overhead and number of packets drop between the nodes of that edge. This paper clearly depicts the application of selection method of Genetic Algorithm to find an optimal and reliable route (path) that is best suited to transfer data packets from one node (THE SOURCE NODE) of a wired network to the other node (DESTINATION NODE) of a wired network. This is similar to the interpretation of the Bridge Problem done by Konigsberg, first of all, in the history of network theory. Using Graph Algorithms is preferable because they successfully overcome the shortcomings of many other similar approaches, and search for the reliable solution in a vast search space i.e. do not fail even for large inputs.

The shortest path problem can be defined as: given a weighted graph (that is, a set V of vertices, a set E of edges, and a real-valued weight function f: $E \rightarrow \mathbf{R}$), and one element s of V (i.e. a distinguished source vertex), we have to find a path P from s to a v of V so that, $\sum$f(p), where p P is minimal among all paths connecting s to v.

The remaining paper is organize as follows, the section 2 describe the background study and analysis of the Genetic algorithm. Section 3 describes the importance of the selection mechanism in the Genetic Algorithm. The Section 4 describes the different selection method. In section 5 we end with the conclusion and future scope.

2. Genetic Algorithm

Genetic Algorithms (GAs) are adaptive heuristic search algorithm based on the evolutionary ideas of natural selection and genetics that mimic natural biological evolution. They represent an intelligent exploitation of a random search used to solve optimization problems. Genetic algorithms are broadly used in optimization problems. Although randomized, GAs are by no means random, instead they exploit historical information to direct the search into the region of better performance within the search space. They facilitate a good alternative in problem areas where the number of constraints is too large for humans to efficiently evaluate.

Basic genetic algorithm (GA) is generally composed of two processes. The first process is selection of individuals for the production of the next generation and the second process is manipulation of the selected individuals to form the next generation by crossover and mutation techniques.

The basic techniques of the GAs are designed to simulate processes in natural systems necessary for evolution; especially those follow the Charles Darwin’s principles of "Survival of the Fittest”. This principle is similar to competition among individuals for scanty resources in nature results in the fittest individuals dominating over the weaker ones.

3. Role of Selection Operator in Genetic Algorithm

The selection mechanism determines which individuals are chosen for mating (reproduction) and how many offspring each selected individual produces. The main principle of selection strategy is “the better is an individual; the higher is its chance of being parent.” However, worst individuals should not be discarded and they have some chances to be selected because it may lead to useful genetic material. A good search technique must find a good trade-off between exploration and exploitation in order to find a global optimum. Hence, it is important to find a balance between exploration (i.e. poor solutions must have chance to go to the next generation) and exploitation (i.e. good solutions go to the next generation more frequently than poor solutions) within the mechanism of the selection.

The choice of the selection of method is somewhat related to selection pressure which is defined as the degree to which the better individuals are favored. The higher the selection pressure, the more the better individuals are favored. This selection pressure drives the GA to improve the population fitness over the successive generations. GA’s should be able to identify optimal or nearly optimal solution under a wide range of selection pressure. However, if the selection pressure is too low, the convergence rate will be slow and the GA will take a longer time to find the optimal solution. If the selection pressure is too high, there is an increased chance of GA prematurely converging to an incorrect (suboptimal) solution.

There are two types of the selection schemes

i. Proportionate based Selection
ii. Ordinal based Selection

Proportionate based selection picks out individual on the basis of their fitness value relative to the fitness of the other individuals in the population. Ordinal based selection schemes selects individual on the basis of their rank within the population.

4. Methods of Selection of Chromosomes

4.1 Roulette Wheel Selection Method

In proportional roulette wheel, individuals are selected with a probability that is directly proportional to their fitness values i.e. an individual's selection corresponds to a portion of a roulette wheel. The probabilities of selecting a parent can be seen as spinning a roulette wheel with the size of the segment for each parent being proportional to its fitness. Obviously, those with the largest fitness (i.e. largest segment sizes) have more probability of being chosen. The fittest individual occupies the largest segment, whereas the least fit have correspondingly smaller segment within the roulette wheel. The circumference of the roulette wheel is the sum of all fitness values of the individuals. The proportional roulette wheel mechanism is depicted in Fig.

If Fi is the fitness value of the i^{th} string in the population, then probability of its selection is

$$P_i = F_i / \sum^{n}_{j=1} F_j$$

Where n is the population size.
Pi is probability of ith string to be selected.

The whole process of roulette wheel selection is as follows:

- Find the probability of each string (Pi).
- Find cumulative probability for each string $(C.P.)_i = \sum^{i}_{j=1} P_j$
- Create n-random numbers between 0-1.
- Find the selected string number by comparing random number with cumulative probability.
- Find number of copies of each selected string.
- Larger the number of copies more will be the chance of the selection of population.

For roulette wheel if the search for the location of the chosen slot is performed via linear search from the beginning of the list, each selection requires O(n) steps, because on average half the list will be searched. Overall, roulette wheel selection performed in this method requires O(n2) steps, because in a generation n spins are required to fill the population. Roulette wheel selection can be hurried somewhat, if a binary search is used to locate the correct slot. This requires additional memory locations and an O(n) sweep through the list to calculate cumulative slot totals, but overall the complexity reduces to O(n log n), because binary search requires O(log n) steps per spin and n spins.

4.2 Elitism

Idea of elitism has been already introduced. When creating new population by crossover and mutation, we have a big chance, that we will lose the best chromosome. The idea here is to arrange the chromosomes in the decreasing order according to their fitness values. Then apply the selection with each two chromosomes in the arranged set. In this way, Genetic Algorithm will be applied between strong chromosomes or between weak chromosomes. This means there is no chance to apply Genetic Algorithm between weak and strong chromosomes.

Elitism is name of method, which first copies the best chromosome (or a few best chromosomes) to new population. The rest is done in classical way. Elitism can very rapidly increase performance of GA, because it prevents losing the best found solution. The time Complexity of Elitism is O(MN2), where M is a number of objectives and N is population size.

4.3 Rank Based Selection Method

Rank-based roulette wheel selection is the selection strategy where the probability of a chromosome being selected is based on its fitness rank relative to the entire population. Rank-based selection schemes first sort individuals in the population according to their fitness and then computes selection probabilities according to their ranks rather than fitness values. The worst fitness has the rank 1, next has 2 and the best has rank N (where N is the no. of population). Hence rank-based selection can maintain a constant pressure in the evolutionary search where it introduces a uniform scaling across the population and is not influenced by super-individuals or the spreading of fitness values at all as in proportional selection.

The calculation of the time complexity of ranking requires the consideration of these separate steps. Sorting can be performed in O(n log n) steps, using standard techniques. Thereafter, we know from previous results that proportionate selection can be performed in something between O(n) and O(n2). Here, we will assume that a method no worse than O(n log n) is adopted, concluding that ranking has time complexity O(nLog n).

4.4 Tournament Selection Method

GA uses a strategy to select the individuals from population and insert them into a mating pool. Individuals from the mating pool are used to generate new offspring, which are the basic for the next generation. As the individuals in the mating pool are the ones whose genes will be inherited by the next generation, it is desirable that the mating pool consists of good individuals. A selection strategy in GA is simply a process that favours the selection of better individuals in the population for the mating pool.

Conditions for tournament selection are
1. The total no of matches will be equal to number of teams.
2. No team can play more than two matches.

A competition is held between the Chromosomes (individuals) of a population .Winner of tournament is the route having highest fitness value .The winner is selected to generate offspring.
The time Complexity of Tournament Selection is O(n).

5. Conclusion

The novelty of this paper lies in the fact that it successfully establishes the surety of finding the optimal path due to the usage of four different techniques. This paper has compared the expected behavior of four selection schemes on the basis of their performance and takeover time computation. Roulette wheel is found to be extremely slower than other five schemes. Tournament Selection and Rank Selection are found to be best in different situations. Also Tournament Selection has the better convergence criteria. Although the actual performance is very much dependent on the different criteria at the time of selection of chromosomes, these criteria could be anything like type of population, type of encoding used, number of chromosomes in population etc.

Hence we observe that using Elitism, Roulette Wheel selection, Rank Selection and Tournament Selection, the shortest path to route a packet from one node (SOURCE NODE) of a wired network to another node (DESTINATION NODE) of a wired network is successfully found out but the Rank Selection and Tournament selection give the best result.

The Genetic Algorithm is based on the Theory of Randomness. The Theory of Randomness says that if the values are chosen, then the values are chosen in approximately equal intervals. Thus in all the methods, the higher the value of fitness function, the higher will be the chances of selection. Hence the Genetic Algorithm provides either the optimum cum reliable solution most of the times, or somewhat close solution to the optimal solution a very few times, on the basis of randomness.

In future there is scope to work upon the extension of this paper that is to work upon finding out the shortest path between variable source and variable destination in the wired network. Also calculating the shortest and the most reliable route between any two nodes in a wireless network can be yet another field of study after this paper.

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