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General Article

A Study of Genetic and Heuristic Algorithm for Traveling Salesman Problem

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Abstract

Genetic algorithm is an algorithm that behaves in a way similar to the evolution process of the mankind, i.e. the crossing of the chromosomes. Heuristic algorithm is another algorithm of Artificial Intelligence that improves the speed of solving a problem. They are very common Algorithms in Artificial Intelligence that are used for various complex problems. Traveling Salesman Problem is NP- Hard problem in combinatorial optimization that finds its applications in manufacture of microchips, planning, logistics etc. In this paper we study the Genetic Algorithm and Heuristic algorithm for Traveling Salesman Problem individually, with their respective drawbacks. In the next part of the paper we compare both the algorithms with respect to the traveling salesman Problem. Finally we study the combination algorithm of Genetic algorithm and Heuristic algorithm, again for the Traveling Salesman Problem and give its advantages over both the algorithms.

Keywords: *Heuristic Algorithm, Genetic Algorithm, Traveling Salesman Problem, Genetic- Heuristic combination, Artificial Intelligence Algorithms*

1. Introduction

The aim of this paper is to establish a relationship between genetic algorithms and heuristic search algorithms in the field of Artificial Intelligence. Genetic algorithm is a search technique used in intelligent computing, to obtain approximate solutions to optimization and search problems, and is often called as GA. Genetic algorithms are applicable in bioinformatics, economics, chemistry, engineering, manufacturing,phylogenetics, mathematics, computational science and other fields. The goal of a heuristic is to obtain a solution in a reasonable time frame that is good enough for solving the problem at hand. The solution may not be the best of all solutions to the problem, or it may simply approximate the exact solution. But it is still considerable because finding it does not require a very long time. Both the algorithms have their pros and cons, but the best solution occurs when genetic and heuristic algorithms are combined. The paper explains the same thing for the Traveling Salesman Problem.

The Traveling Salesman Problem (TSP) can be easily stated: Given a complete graph with n nodes, find the shortest Hamiltonian path through the graph. The amount of time required for exact computation of a TSP problem is exponential in N, the size of the problem (John J. Grefenstette(*2009*)).

This paper is mainly divided into three parts the first and the second part explain the traveling Salesman Problem using Genetic and Heuristic Algorithm respectively with advantages and disadvantages of each algorithm. The third part explains the traveling Salesman Problem using a combination of Genetic and Heuristic algorithm.

2. Traveling Salesman problem using genetic algorithm

Genetic Algorithms are Artificial Intelligence algorithms that behave in a way similar to the evolution process of Humans. The algorithms consider its input in any form as chromosomes, and performs functions to generate a result by following the rule of survival of the fittest.

Genetic Algorithm is mainly a machine learning algorithm that is used for solving complex problems, but mostly optimization problems. Traveling salesman Problem is a very common optimization problem.

Genetic Algorithm when used to solve the Traveling Salesman Problem mainly consists of selection, crossover, mutation, and finally the survival of the fittest (Braun, Heinrich, 1991).

For example, if we want to find a TSP solution for N city tour, the steps are as follows:

Selection: A “population” i.e. a set of many random tours is created. A greedy initial population approach is used by giving preference to the cities that are close to each other.

Crossover: Take two shorter tours as “parents” from the “population” and then combine them to make two new tours i.e. “child”. The child tour is expected to be better than the “parent” tour.

Mutation: Sometimes, the “child” tours are mutated, so that all the tours in the “population” do not look identical.

Survival of the fittest: Two longer tours from the “population” at a time are replaced by new “child” tours.

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Hence the size of the "population" remains the same.
The entire process of creating the "child" tours is repeated till the destination is reached using the shortest path.

Although the GA is simple to implement it has the following drawbacks:

- GA's prove inefficient due to poorly known fitness functions which generate bad chromosome blocks in spite of the fact that only good chromosome blocks cross-over (Prof.Dr. Riko Safaric, Asst. Prof. Andreja Rojko(2006)).
- There is no absolute assurance that a genetic algorithm will find a global optimum solution. It happens very often when the populations have a lot of subjects (Prof.Dr. Riko Safaric, Asst. Prof. Andreja Rojko(2006)).
- Like other artificial intelligence techniques, the genetic algorithm cannot guarantee constant optimisation response times. The difference between the shortest and the longest optimisation response time is much larger than with conventional gradient methods (Prof.Dr. Riko Safaric, Asst. Prof. Andreja Rojko(2006)).
- Using GA the entire "population" is improving, but this could not be assured about an individual within this population (Prof.Dr. Riko Safaric, Asst. Prof. Andreja Rojko(2006)).

3. Traveling Salesman Problem Using Heuristic Algorithm

The application of Heuristic Learning Algorithm requires a non overestimating Heuristic estimate from current state of search tree to the goal state to the destination (Sim Kim LAU, and Li-Yen SHUE, 2001).The algorithm expands the nodes in order of their Heuristic values (Richard E. Korf, 1996). Thus, a Heuristic evaluation function plays a very important role in optimal planning.

For a TSP, a salesman in city i selects his next city as city j, for which the heuristic function is h(i,j) is the minimum among all h(i,k) costs, where k are the pointers of the unvisited cities. The function value can be calculated using Euclidian (Airline) distance which is an estimate of the highway distance between a pair of locations (Sim Kim LAU, and Li-Yen SHUE, 2001).

The Heuristic Algorithm maintains a Closed List of those nodes that have already been expanded and an Open List of those nodes that have been generated but not expanded. The algorithm begins with the initial state on the open list. At each iteration, a node on the open list with the minimum h(n) value is expanded, all of its children are generated and is placed on the closed list. Children are then worked upon by the heuristic function, and they are placed on the Open list in order of their heuristic values. Until a goal state is chosen for expansion, the algorithm continues (Richard E. Korf, 1996).

Heuristic algorithm has some drawbacks as stated below:

- Running time for larger problems can be reduced but only by sacrificing some effectiveness leading to several tradeoffs between effectiveness and running time.
- Domain expertise is required to be able to work with heuristic algorithms making these domain experts highly expensive to hire.
- Heuristic Algorithm does not always guarantee an optimal solution. There are chances that the solution found is sub-optimal.
- Problems that are not 2-dimensional and don't consider Euclidean distances become difficult to solve.

4. The Comparative Study and Study of Combination of Heuristic and Genetic Algorithms

We have studied both the algorithms for the Traveling Salesman Problem in detail. There are some of the obvious differences between both the algorithms:

- The Genetic Algorithm almost never has a start state and goal state, whereas the Heuristic algorithm always has a well-defined start and goal state.
- Genetic Algorithm always provide a optimal solution whereas the Heuristic algorithm may provide sub-optimal solution.
- The Heuristic algorithm maintains two sets of the edges (the distance between the cities for a Traveling Salesman Problem)- open list and closed list whereas the genetic algorithm has only one set i.e. the population.
- The Genetic algorithms are slower when compared to Heuristic algorithms but strongly follow the policy of the survival of the fittest.

Use of just pure genetic algorithm gives optimal but delayed results. Heuristic functions give faster solutions but acquire more space since cost of each node needs to be saved. Use of heuristic function along with GA gives optimal and faster results as studied by researchers. The studies can be summarized as below.

The best tour length with just genetic algorithm without heuristic information is longer than that obtained with the use of pure order crossover algorithm (Kylie Bryant, Arthur Benjamin, 2000).
Furthermore, the matrix crossover method is better because it uses edges which contain the costs rather than positions that connect cities. However, this method is more time consuming as compared to an integer representation method (Kylie Bryant, Arthur Benjamin, 2000).

An algorithm that uses only the 2-opt mutation operator with no crossover performed decently, however not as well as the matrix crossover method. It performed badly with problems where the number of cities is huge (Kylie Bryant, Arthur Benjamin, 2000) .

In combination with the 2-opt and Or-opt mutation operators, the heuristic crossover sometimes gives the best known solution for that problem, and otherwise provides an almost correct solution (Kylie Bryant, Arthur Benjamin, 2000).
Hence, from the above solutions, we see that genetic algorithms perform best for the traveling salesman problem when using a matrix representation with matrix crossover or a heuristic crossover (Kylie Bryant, Arthur Benjamin, 2000).

Conclusions

For the travelling salesman problem, genetic algorithms provide good solutions but there are certain tradeoffs between optimality and time constraints. Heuristic search provides results in less time but takes more space. Both genetic and heuristic algorithms have their own set of disadvantages. As studied and proven by researchers, a combination of GA and heuristic function works best at providing an optimal result to the TSP. Working out the combination though is tedious task, it takes the advantages of both Heuristic and Genetic Algorithm. Thus, the combination of Heuristic and Genetic Algorithm has an enormous future scope for solving complex and time critical problems.

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