COSC 6368

ARTIFICIAL INTELLIGENCE

PROJECT-1

TRAVELLING SALESMAN PROBLEM

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**Introduction:**

The travelling salesman problem is a NP-Hard problem that has (N-1)!/2 solutions in the search space which increases exponentially as the value of N increases, where N is the number of Cities.

The strategies are of two types

1. Simple(SIM) like any greedy search which picks any solution from the state space (not optimal)
2. Sophisticated(SOPH) like evolutionary algorithms which iterate over the solution space and return a sub-optimal solution.

For the simple method I am using a greedy search(SIM-Nearest Neighbour) and for the sophisticated method a evolutionary algorithm(SOPH-Genetic Algorithm). I have also used Simulated Annealing and Tabu Search strategies. The crossover methods like single point crossover, two point crossover, uniform crossover have also been tried. The selection mechanisms like Tournament selection and Roulette Wheel Selection are also tried.

**Evolution Of The Project:**

If strategies like Hill Climbing is chosen then we might be at a risk of reaching the local optima and never finding the global optimum. If we apply a heuristic technique like A\* algorithm then it is not easy to find the heuristic value which is the crow flying distance between two cities.

So an algorithm that iterates over the solution space and tries to reach a sub optimal solution is the best approach.

Tabu Search is where a random solution is generated and two cities are swapped and the cost is checked. The best solution is taken to the next iteration.Here, a tabu is placed on these two cities so that they are not swapped repeatedly. The tabu value is decreased for every iteration until the cities the free to be swapped again. But this has a problem where sometimes good choices are also not made because of the tabu on the city/node.

Simulated Annealing is similar to the Tabu Search where the iterations are based on a temperature and cooling rate. A maximum temperature is taken and is cooled for every iteration. And in each iteration the cities are swapped at a random point and the tour distance is checked, and the best solution is considered for the next iteration.

In Genetic Algorithm, first a random set of solutions are taken from the search space- called a Population. Now operations like crossover and Mutation is performed on this set of solutions and a new generation of solutions is generated. This goes until a limit and the best solution in the last generation is given as the output.

Genetic algorithm has a high probability of finding the better solution because it iterates over generations, and is capable of searching a vast solution space. Selecting a tournament is where two random parents are selected for crossover

Genetic algorithm with tournament selection and two point crossover is done for SOPH as it is yielding better results than Simulated Annealing and Tabu Search.

**Employed Search Strategies**

1. **Greedy Search- Nearest Neighbor- SIM**

The Simple strategy is a greedy search which chooses a node and finds the next nearest city from the current city and then the next nearest city to that city. This process is repeated until all the cities are visited and reaches the initial city again from the final destination to complete the round trip.

1. **Genetic Algorithm- Evolutionary Technique – SOPH**

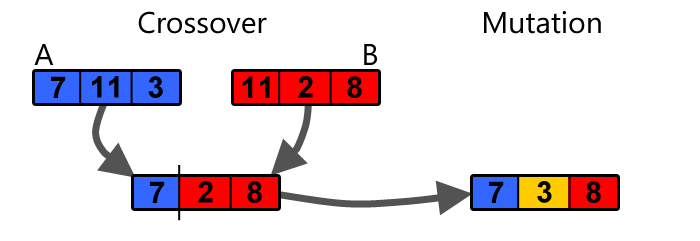
Survival of the fittest describing the mechanism of natural selection is the key to genetic algorithm. On the initial set of solutions(Population), a tournament selection, crossover and mutation are applied onto the Population and the fittest population is carried to the next generation.

During Tournament selection a fixed size of random solutions are selected from the current generation and the fittest is taken as one parent. Similarly, another parent is generated.

In two-point crossover, two random start and end points are defined and those are considered as indexes of the substring from one parent and the remaining cities are placed from the other parent.

In Mutation two cities are randomly selected and swapped. We can have a mutation rate which determines if the mutation is performed or not. Mutation can be done iteratively but it might decrease the quality of the generated solution

For better Visual understanding



1. Simulated Annealing(Employed-but not included)

In this strategy, two positions are selected in a random solution and are swapped and then the energy(cost) is calculated. Then the energies of the initial solution and newly generated solution are compared and the best one is taken to the next iteration. The iterations are based on the temperature of the system which is initially set to a large value and cooled for every iteration.

**Results**

1. SIM- Nearest Neighbor

|  |  |  |  |
| --- | --- | --- | --- |
| **Number Of Nodes** | **Cost Function - C1** | **Cost Function - C2** | **Cost Function - C3** |
| 10 | 426 | 60 | 1068 |
| 30 | 466 | 821 | 33408 |
| 60 | 526 | 2636 | 277418 |
| 120 | 646 | 13411 | 2261238 |
| 200 | 806 | 37527 | 10547398 |

The simple strategy is run and evaluated for the given cost functions and the above results are obtained.

1. SOPH- Genetic Algorithm

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Number Of Nodes** | **MEB** | **Cost Function-C1** | **Cost Function-C2** | **Cost Function-C3** |
| 10 | 20000 | 430 | 60 | 870 |
|  | 100000 | 426 | 56 | 818 |
|  | 200000 | 426 | 56 | 818 |
| 30 | 20000 | 526 | 418 | 25768 |
|  | 100000 | 497 | 392 | 25672 |
|  | 200000 | 476 | 367 | 25578 |
| 60 | 20000 | 732 | 5109 | 214366 |
|  | 100000 | 582 | 3287 | 210236 |
|  | 200000 | 563 | 2192 | 209288 |
| 120 | 20000 | 1247 | 34756 | 1789044 |
|  | 100000 | 1242 | 32523 | 1713948 |
|  | 200000 | 1071 | 31042 | 1710596 |

In genetic algorithm for greater values of MEB the algorithm is giving better results. This shows that if we allow the algorithm to iterate more

by giving greater population sizes and greater number of generations the value of cost will reduce.

1. SOPH – Simulated Annealing

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Number Of Nodes** | **MEB** | **Cost Function-C1** | **Cost Function-C2** | **Cost Function-C3** |
| 10 | 20000 | 1072 | 109 | 1066 |
|  | 100000 | 823 | 79 | 671 |
| 30 | 20000 | 1103 | 2724 | 29641 |
|  | 100000 | 712 | 1296 | 28283 |
| 60 | 20000 | 2232 | 9387 | 236581 |
|  | 100000 | 1707 | 4287 | 228993 |
| 120 | 20000 | 5075 | 237799 | 2001849 |
|  | 100000 | 4791 | 282394 | 1926061 |

**Interpretation Of Results**

1. If both the sophisticated strategies are compared, genetic algorithm yields better results.
2. Genetic algorithm gives better results at higher MEB values. This means that with more iterations and population it gives better results.
3. For Cost Function-1 the Simple and sophisticated strategies are almost the same, but Genetic algorithm gives better results for Cost Function-3 because all the values in this matrix are in the powers of 2. So sophisticated strategy deals better with larger values.
4. And with higher number of Cities the difference between genetic algorithm and greedy search grows significantly.
5. This shows that in Real-World evolutionary algorithm are efficient in calculating a better route.
6. Also, if we do it multiple times we get different values for the same input parameters, this shows the randomness of the algorithm. We can perform it multiple times and select the best value from the algorithm.
7. This shows that more than Mutation(swapping operation) the crossover operation yields better results because it still holds some of the edges from the parents.

**Resources**

1. <https://en.wikipedia.org/wiki/Crossover_(genetic_algorithm)>
2. <https://en.wikipedia.org/wiki/Mutation_(genetic_algorithm)>
3. <http://docs.oracle.com/javase/tutorial/uiswing/>
4. <https://www.researchgate.net/publication/229046115_A_Genetic_Algorithm_with_a_Tabu_Search_GTA_for_Traveling_Salesman_Problem>
5. <http://www.theprojectspot.com/tutorial-post/applying-a-genetic-algorithm-to-the-travelling-salesman-problem/5>
6. <https://dl.acm.org/citation.cfm?id=2183091>
7. Softwares Used : Eclipse IDE(for java code development),