Design & Analysis of Algorithms
Project Report

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1. Abstract

The Traveling Salesman Problem (TSP) is one of the most famous benchmarks, significant, historic, and very hard combinatorial optimization problems. The purpose of this project was to implement the Traveling Salesman Problem with the help of the cycle crossover operator (CX) and the modified cycle crossover operator (CX2) and to analyse the comparison between them. The CX2 was proposed in a research article "*Genetic Algorithm for Traveling Salesman Problem with Modified Cycle Crossover Operator*". The TSP, described as the minimization of the total distance travelled by touring all cities exactly once and returning to depot city, is considered as an NP-hard problem in the fields of Computer Science as it can be both symmetric and asymmetric, depending on the matrices, and due to this, for n cities there are $(n - 1)!$ possible ways to find the tour after fixing the starting city for asymmetric and it's half for symmetric TSP.
After the analysis and comparison, we found out that CX2 is a more suitable solution for the travelling salesman problem than the original CX.

2. Introduction

As the article suggested, we only looked at the TSP through path representations.

The TSP is considered as an NP-hard problem in the fields of Computer Science as it can be both symmetric and asymmetric, depending on the matrices, and due to this, for n cities, there are $(n - 1)!$ possible ways to find the tour after fixing the starting city for asymmetric and it's half for symmetric TSP.

The drawback is that often many times this technique produces offspring that are the same as their parents. And also, the time complexity was ___.

Therefore, we used the modified version of the cycle crossover operator. It is a very similar one, but it generates both offspring from parents using cycle(s) till the last bit.

3. Programming Design

To begin with, we implemented the Traveling Salesman Problem in Python and on its IDE, PyCharm, once with the cycle crossover operator (CX), and the other time with it's modified version (CX2) as proposed in the research article.

The major difference between the two crossover operators is that the original uses a genetic algorithm to create offspring in such a way that each bit with its position comes from one of the parents. In the first bit, either of the two parents from the same position is chosen. Next, every bit in the offspring should be taken from other of its parents with the same position of the number. This is looped till the number that is already in the path (or list) arrives. So now the second parent is used. This is done to fill the rest of the empty spaces or crosses. However, in the CX2, the first bit is chosen from the second parent as the first bit of the first offspring. Then. that selected bit is found in the first parent and the exact position is picked in the second parent to place in the offspring. Then the next bit chosen would be found again in the first parent and, finally, the exact same position bit which is in the second parent will be selected for a 1st bit of the second offspring.

Next, the selected bit from earlier would be found in the first parent and the exact same position bit would be picked which is in the second parent as the next bit for the first offspring. For the first offspring, we choose bits only with one move and two moves for second offspring's bits. This is looped until the end of the path.

Both are run and their time complexities on benchmarks were compared.

4. Experimental Setup

- Code for Cycle Crossover Operator:

- Code for modified Cycle Crossover Operator:

5. Results and Discussion

- Time Complexity Analysis:

- Comparison Analysis

6. Conclusion

Two crossover operators have been implemented to solve the TSP. The CX along with proposed crossover operator CX2 is mainly focused here. At first, we apply the two-cycle operators on a population and found that CX2 performs better than its original CX crossover. We observed that for a large number of instances, the proposed operator CX2 is performing much better than the other operator. Therefore, we conclude that CX2 is a better crossover operator that its original version.

7. References

Research Article - *Genetic Algorithm for Traveling Salesman Problem with Modified Cycle Crossover Operator*