Travelling Thief Problem - An approach using Evolutionary Computation

Andres Francisco José Corso Pinzón

***Abstract*—This paper presents the first approach to the Travelling Thief Problem solving the two sub-problems (Travelling Salesman Problem and Knapsack Problem) and the problem itself through several techniques studied in the Evolutionary Computation in the Universidad Nacional de Colombia. There are 4 kind of algorithms used to solve the problem.**

***Index Terms*—Genetic Algorithm, Travelling Thief Problem**

I. Introduction

The travelling thief problem (TTP) [1] is a combination of two well known NP-hard problems, Travelling Salesman Problem (TSP) and Knapsack Problem (KP). In TSP, the objective is to find an optimal tour between n number of cities in terms of distance, with the condition that the salesman just can pass for each city once. On the other hand, the target of KP is to put some objects in a rucksack which has a limit of weight. Those objects have a weight and a value, so the objective is to put the objects that represent the best profit with the constrain of the maximum weight of the knapsack.

To join those two problems, TTP adds some additional parameters. First, the concept of speed which decrease directly proportional with the weight put in the bag. Second, the objects are distributed in the cities. Third, the objects loss value with the pass of the time.

Those 2 classic problems have been approached using several technique. Those include dynamic programming [2], linear-programming [3] and genetic algorithms [4] [5].

The common approach using Evolutionary Computation employ the Chained Lin-Kernighan heuristic to create a fixed tour for the TTP solution, and then try to solve the KP.

To compare the different solutions, some test case are downloaded. For the TSP solution from TSPLIB are used. The examples for KP are both low and high dimension. Finally, the University of Adelaide [1], provides some cases to prove the algorithms of the TTP.

This first approach to the Genetic Algorithms (GA) is to solve the TSP and the KP problems. Then, the model 1 presented in [1] is solve using Multimodal approach. And the model 2 is used in the Multi-Objective and the Co-Evolution algorithm.

Firstly, this document presents in section II the description of all the proposed techniques to solve the problems. Then, in section III the obtained results are presented and analyzed. Finally, some conclusion are presented in section IV.

Corso A. is with the Universidad Nacional de Colombia, Cr 45 N° 26-85, Bogota, Colombia (e-mail: acorso@unal.edu.co).

II. Algorithm

A. Genetic Algorithm

The nature of each problem is different. The tour of the salesman is a list of each city, for this the most common representation is a permutation of all cities. On the other hand, the KP has a binary representation. The fitness function in the case of TSP is the distance walk by the salesman. While, in the case that the knapsack exceed the maximum weight the value is 0, otherwise, the profit made with the items in the bag.

Several operators were developed for each problem. The crossover operators include Davis' Order Crossover (OX1), Position Based and Modified Order Crossover (MOC) for permutation, and Binary Crossover for binary representation. Besides, the mutation operators incorporate Inversion, Scramble and Swap for TSP problem and Binary mutation for KP.

The selection of the parents in both cases were made by a size 4 tournament.

B. Multimodal

For the multimodal approach the model presented as TTP1 in [1] is used. The equations 1-3 summarize the problem where the objective is obtain the biggest profit taking into account that the knapsack has a cost of use.

For have different niche in the population and method called Shared Fitness is used in the selection problem. This assure that the individuals who have less neighbours have more chance to be selected.

$$G(x,z) = g(z) - R * f(x,z) \tag{1}$$

$$f(x,z) = t_{x_n,x_1} + \sum_{i=1}^{n-1} (t_{x_i,x_{i+1}}) \tag{2}$$

$$g(z) = \sum_{i=0}^{m} p_i * z_i \tag{3}$$

C. MultiObjective

In this section the model TTP2 is used. The equations 4 and 5 shows how the problem is driven. This model include the variable that the items loss value according with the time that the thief carry them.

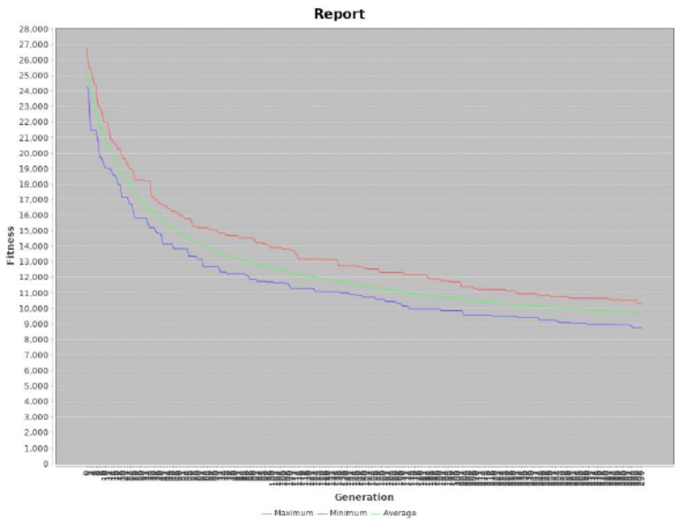

Fig. 1. berlin52

$$f(x,z) = t_{x_n,x_1} + \sum_{i=1}^{n-1} (t_{x_i,x_{i+1}}) \tag{4}$$

$$g(x,z) = \sum_{i=0}^{m} p_i * Dr^{\frac{T_i}{C}} \tag{5}$$

D. CoEvolution

This uses the same model than Multiobjective, but in this case there are two population who interact through friendships between the individuals, one population minimize the f function while the other minimize the g function.

III. Experiments

A. Genetic Algorithm

1) Traveling Salesman Problem: The data to test the implementation was the problems berlin52 and att48 provided by TSPLib. Several configuration of the operators were performed.

2) Knapsack Problem: The files used to test the GA of the KP have 200 and 1000 items.

B. MultiObjective

The pareto front is presented in Figures 5 and 6.

C. CoEvolution

Figures 7 and 8 show the behaviour of the funcions f and g. This is comparable with the pareto front found with the multiobjective approach.

IV. Conclusion

A technique to solve several KP and TSP problems are presented. The heuristic algorithm usually converge to local optimums, but can be an option to find acceptable solution for NP-hard problems. Other approach to solve the TTP are presented.

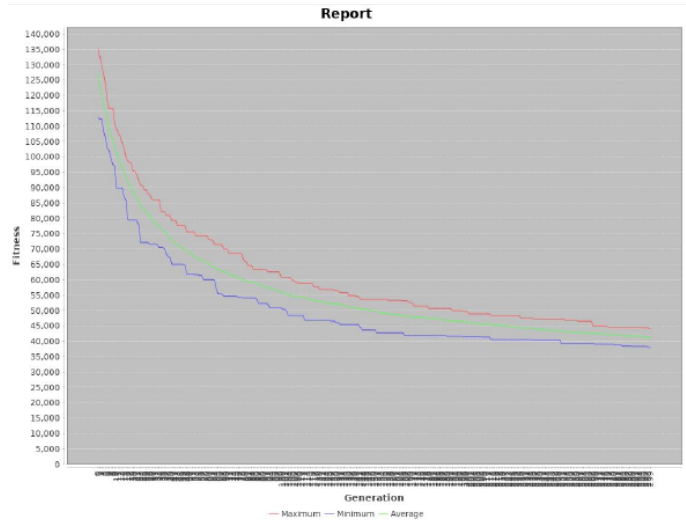

Fig. 2. att48

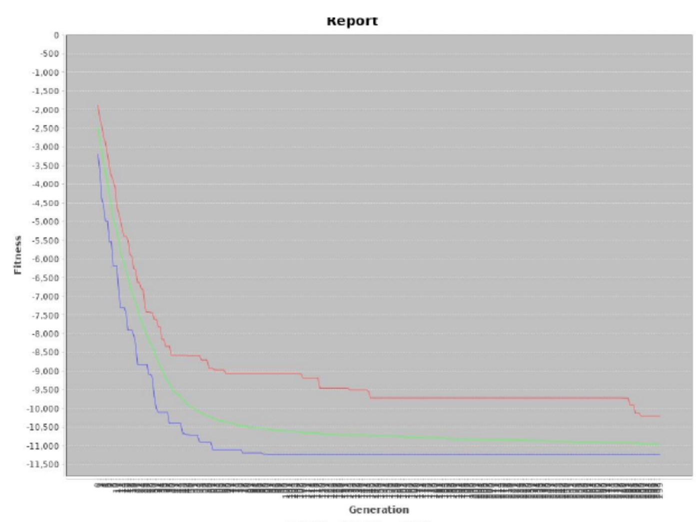

Fig. 3. 200 Items

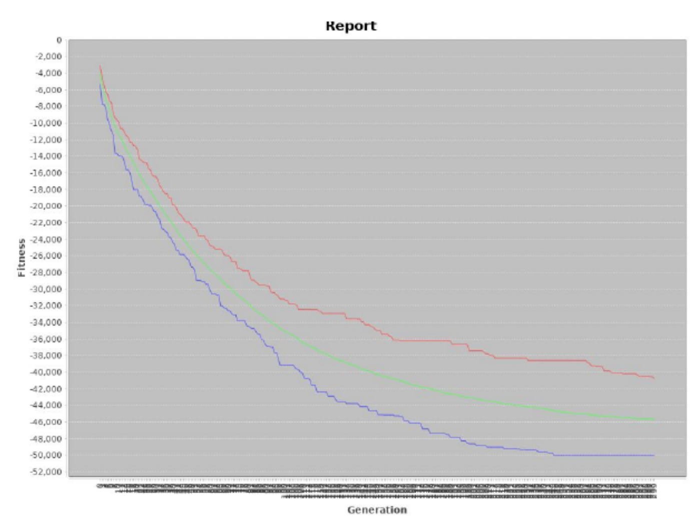

Fig. 4. 1000 Items

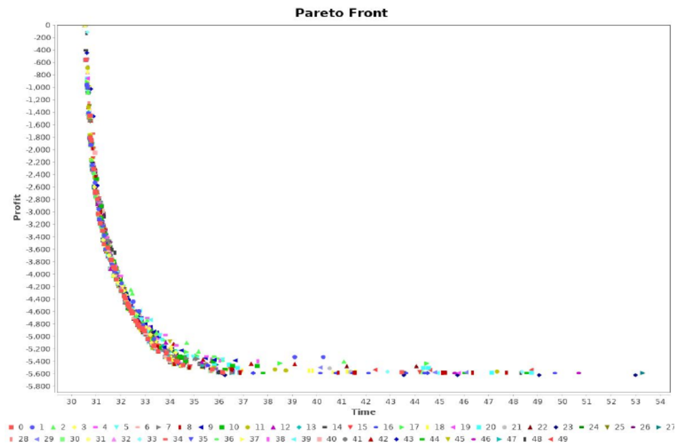

Fig. 5. 10 Cities, 15 Items

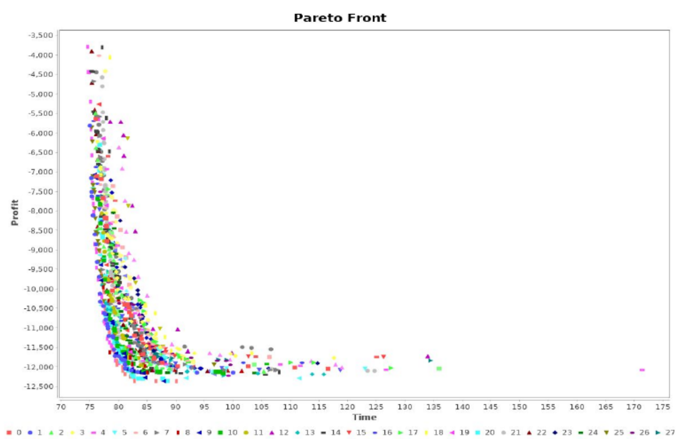

Fig. 6. 20 Cities, 25 Items

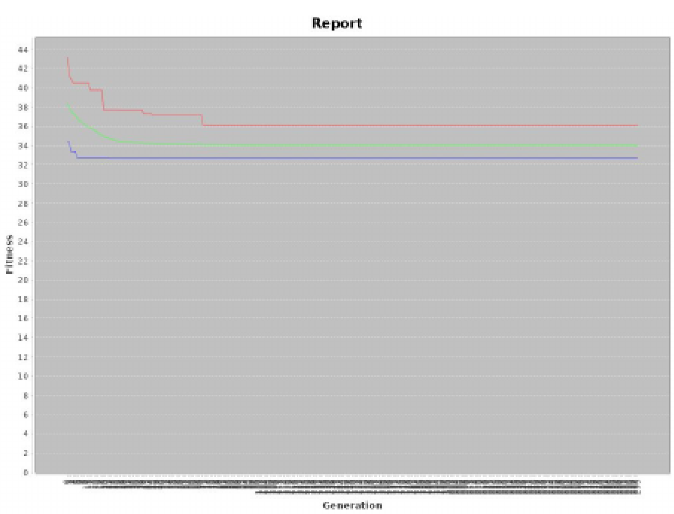

Fig. 7. 10 Cities, 15 Items, f function

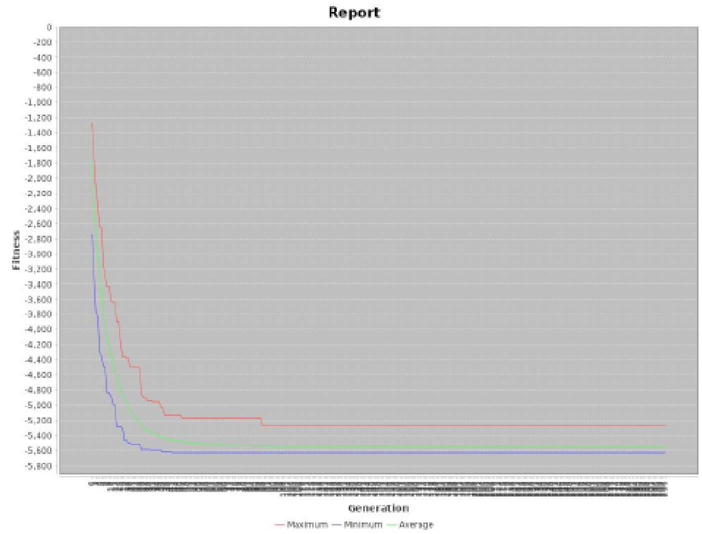

Fig. 8. 10 cities, 15 items, g function

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