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Hybrid Metaheuristic for the Traveling Salesman Problem

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Abstract

This study proposes a metaheuristic for solving the Traveling Salesman Problem that is implemented by a hybrid system made up of a stochastic descent algorithm called Kangaroo and a Genetic Algorithm. The hybrid system is based on the collaboration between the iterated solution improvement method and a well-known metaheuristic method. A genetic algorithm performs to diversify the search space. After completing the task of genetic algorithm, the kangaroo algorithm tries to intensify the results from genetic algorithm. The method was applied to well-known problems in literature. Deviations from the optimum values and the results were compared. When Kangaroo algorithm is used in combination with genetic algorithms, it produces better results than when is used by itself.

Key Words: Genetic algorithm, kangaroo algorithm, traveling salesman problem, hybrid, metaheuristic, neighborhood function

1. Introduction

Both Kangaroo Algorithm (KA) and Genetic Algorithms (GA) are heuristic procedures for the resolution of optimization problems. In this study, a hybrid metaheuristic is proposed for solving traveling salesman problem; the solution method is based on the collaboration between the iterated solution improvement method kangaroo algorithm and the GA. The system has the exploration power of the KA and the intensification ability of the GA.

Traveling salesman problem is defined as a task of finding of the shortest Hamiltonian cycle or path in complete graph of N nodes. TSP has attracted the attention of researchers because can be considered as NP-hard. The problem was first formulated in 1930. Hassler Whitney at Princeton University introduced the name travelling salesman problem [1] and is one of the most intensively studied problems in optimization. It is used as a benchmark for many optimization methods. Since it is almost impossible to find the best solution for these problems in polynomial time, various heuristic and intuitive methods have been developed.

Iterative methods can be useful to find the sub-optimal solutions for NP-hard problems. In the literature there are two kind of iterative methods. If the iterative method aims to improve a unique solution, than it is called *iterated solution improvement* (ISI). Tabu search, simulated annealing and stochastic descent methods (like Kangaroo method) are ISI methods. On the other hand if the method aims to improve a set of solutions, than it is called *iterated population improvement* (IPI). Genetic algorithms are an example of the IPI method [2].

Kangaroo Algorithm was first proposed by Pollard [3]. In this article, Pollard was emphasized theory of methods, and performance of the method has not been tested on a problem. Since it is the first study related with Kangaroo algorithm, the study has been source of inspiration for future studies. Van Oorschot and Wiener developed the parallel version of the Pollard's theory in 1996 [4]. They implemented the parallel version of the Kangaroo algorithm to the cryptology. Minzu and Hendrioud [5] used the KA to solve single and mixed-model assembly line balancing problems.

Kangaroo algorithm is an iterative solution improvement method which has been developed inspired by the simulated annealing method. KA is also classified as a neighborhood search algorithm. The solution of the discrete optimization problems starts a certain point of the solution space, and then closes neighborhoods to being search according to particular neighborhood function. This phase is called as *descent.* The initial solution is called and neighbor solutions (′) are examined in every step. If a new improvement is no longer possible in a certain number of iteration, a procedure is performed, in order to escape from the attraction of the local best solution. This procedure can use a different neighborhood definition. At this stage; solution set is changed randomly to scan all different points of the solution space, instead of searching the nearest neighborhoods of the solutions. In procedure; again if there is no improvement in a certain number of iteration, it is returned to procedure. The algorithm can be summarized in steps, as follows [6]:

```
Step 1: Initialize algorithm parameter,
Step 2: Choose an initial solution,
Step 3: Find a new solution  * that solves objective function,
  ← 1;  * ←  ;
Step 4:  if  <          ( , *, )
               else      ( , *, )
         until (the stopping criteria is achieved)
```

and functions are expressed in detail as follows:

```
      ( , *, )
Begin
random generation of a solution   in the neighborhoods of
           ←  +1;
         if  ( ) ≤  ( ) then
         begin if  ( ) <  ( ) then
               begin
                 ← 0; // the better solution value is obtained;
               if  ( ) <  ( *) then  * ←  ;
               end;
                 ←  ; // new solution set is replaced the old one
         end;
End.

    ( , *, )
Begin
random generation of a solution   in the neighborhoods of
          ←  +1;
         if  ( ) ≠  ( ) then
         begin
               if  ( )<  ( *) then  * ←  ;
                 ← 0;
         end;  ←  ;
End.
```

Genetic Algorithm (GAs) is a population based optimization technique that developed by Holland [7, 8]. Chromosomes represent solution variables. This representation can not only be done with binary coding, permutation coding can be used in ordering problems also. With randomly selected permutation order from the pre-determined value range an initial solution is generated. The group of solutions produced with the number of chromosomes (population size) is called Initial Population. Then, the quality of solutions evaluates according to the problem-specific fitness function. Fitness function in our model is total tour cost. New solution candidates are created by selecting relatively fit members of the population and recombining them through various operators: selection, crossover, mutation [9].

The purpose of selection in GA is to offer additional reproductive chances to some population members that are the fittest. The roulette-wheel-selection is used for this proposed GA. The crossover, most important operator for solution space search, is the procedure of creating new chromosomes with randomly selected genes from parent chromosomes. When the crossover operation is applied opposite sides of the pre-determined crossing point are switched across this point. In this paper one-point crossover is used. Mutation plays secondary role in the GA.

"In artificial genetic systems the mutation operator protects against such an irrecoverable loss" [8]. The genes selected with a mutation rate (low probability) are switched randomly. The steps of GA are as follows:

Step 1. Generation of initial population
Step 2. Evaluation of each chromosome
Step 3. Selection
Step 4. Crossover
Step 5. Mutation
Step 6. If stopping criteria is not met go to Step 2
Step 7. Select the best individual as a final solution.

In recent years, efficient hybrid metaheuristics were developed for optimization problems. This study proposes a hybrid metaheuristic that is implemented by a hybrid system made up of a stochastic descent algorithm called Kangaroo and a Genetic Algorithm. Minzu and Beldiman [2] have already proposed a hybrid metaheuristic from by GA and KA to solve single –machine scheduling problem. But our study is the first application of this hybrid method to the traveling salesmen problem.

Fleury and Gourgand [10] used stochastic algorithms, genetic algorithm and simulated annealing based algorithms to solve different sizes single machine flow shop scheduling problems. According to authors, when the time factor is not taken into consideration; annealing type algorithms, especially KA, are more effective, easier to edit with quite good results. They also indicated that good modeled of this type of algorithms are easy to be used in much more complicated problems when they are used as a hybrid especially with genetic algorithms. Pollard [11] used serial and parallel computers to improve the KA in terms of the performance and handled the discrete optimization problems as test problems. In theory the method was developed on mathematical games such as monopoly and card tricks.

Teske [12] analyzed the serial and parallel kangaroo methods in detail. In the implementation part of the study, serial and parallel KA's was applied for a discrete optimization problem with different number of kangaroos (20, 100, and 1000). As a result of the analysis; both of two methods yielded good solutions. In terms of ease of implementation, parallel KA has been recommended for subsequent studies. Minzu and Beldiman [13] used kangaroo algorithm with metaheuristic such as genetic algorithm in their study. They handled the machine scheduling problem, and compared the results of the hybrid algorithm with the stand alone genetic algorithm's results.

Duta et al. [6] proposed a real time control method based on modeling of disassembly by the precedence graph and on a stochastic algorithm, called kangaroo algorithm, in their study. Serbencu et al. [14] proposed a metaheuristic for solving the Single Machine Scheduling Problem that is implemented by a hybrid system made up of an Ant Colony System and a stochastic descent algorithm called Kangaroo. The hybrid system is based on the collaboration between a social type multi-agent system and an Iterated Solution Improvement method. Yılmaz et al. [15] solved flow shop scheduling problems with parallel kangaroo algorithm and they defined the performance criteria as the completion time of the procedure.

2. Mathematical model and solution algorithm

Given a set of cities, and known distances between each pair of cities, the TSP is the problem of finding a tour that visits each city exactly once and then return to start point that minimizes the total distance travelled. In other words, TSP is stated as, given a complete graph, G, with a set of vertices, V, a set of edges, E, and a cost, c_{ij}, associated with each edge in E. The value c_{ij}, is the cost of transferring from vertex i∈V to vertex j∈V. In this state the problem is NP-hard. For an n-city symmetric TSP, there are (n −1)! /2 possible solutions along with their reverse cyclic permutations having the same total cost. In either case the number of solutions becomes extremely large for even moderately large n so that an exhaustive search is impracticable.

$$= \begin{matrix} 1, & h & \\ & 0, & h \end{matrix} \tag{1}$$

$$\tag{2}$$

$$(\, , \,) \in$$

Subject to:

$$= 1 \qquad \forall \quad \in \mathrm{V}, \qquad (3)$$

$$\in$$

$$= 1 \qquad \forall \quad \in \quad , \qquad (4)$$

$$\in$$

$$\in \{0,1\} \qquad (\; , \;) \in \mathrm{E}. \qquad (5)$$

The objective function is to minimize the sum of the cost of visiting each city (i.e. total tour cost). The first and the second constraints state that each city can be visited only once and they prevent the inappropriate solutions.

In this paper, KA, which is applied TSP problems for the first time, is used with GA meta-heuristic. The result which is obtained from KA is used in GA for preliminary populations. Thus, it's provided that GA is started to search from a better point. It is intended to reach optimum or nearly optimum solutions much faster than randomly start. The best result comes from GA with a certain number of iteration is worked over again with KA. Therefore, KA's own performance is wanted to improve with GA. The algorithm is defined as follows:

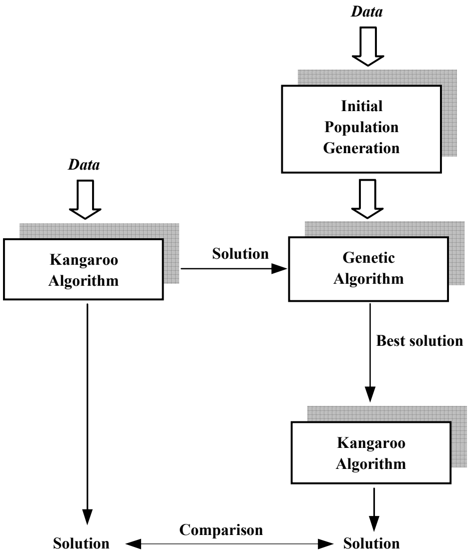

Figure 1: KA and Hybrid System

3. Numerical results/Case study

Computational tests were performed in order to compare the proposed metaheuristic hybrid system with a stand-alone KA. The software developed was coded in MATLAB and the tests were performed on a PC Intel® Core™ 2 CPU 1.86 GHz, 1 GB RAM. Several problems are used in our experiments, which are obtained from a library of TSPs called TSPLIB [16]. The number of iterations was chosen 1000 (for GA and KA in the hybrid metaheuristic), and 2000 for stand-alone KA. Both of two algorithms were run ten times for each problem. After the running, minimum, maximum, mean and the standard deviation from the optimum of the ten results were calculated. The results are shown in Table 1. The optimal values were known for these problems. Thus, the deviation from the optimal value calculated and figured in the Figure 2.

$$= \frac{\quad - \; h \qquad\qquad h \qquad\qquad h}{\qquad\qquad\qquad\qquad} * 100$$

Table 1: The results of KA and KA-GA Hybrid

Problem	Optimum	KA				KA-GA Hybrid			
		Mean	Min	Max	Deviation (%)	Mean	Min	Max	Deviation (%)
gr17	2085,00	2092,70	2085,00	2103,00	0,37	2091.1	2085	2103	0.293
bays29	2020,00	2130,80	2020,00	2333,00	5,49	2043	2020	2092	1.139
swiss42	1273,00	1434,80	1273,00	1686,00	12,71	1392.1	1273	1478	9.356
eil51	426	478,85	440,27	520,38	12,41	461.23	440,27	493.34	8.270
berlin52	7542,00	8726,23	7675,77	9853,07	15,70	8644.7	7675,77	9571.4	14.621
st70	675,00	840,65	739,49	968,59	24,54	796.14	739,49	820.31	17.947
eil76	538,00	631,94	582,17	695,54	17,46	620.86	582,17	656.76	15.401
kroA100	21282,00	28861,27	24277,04	34526,84	35,61	28059	24277,04	32776	31.844
kroB100	22141,00	29435,85	25225,26	34672,82	24,78	25254	25106	25281	14.060
eil101	629,00	760,56	706,12	898,68	20,92	732.03	687.27	764.66	16.380

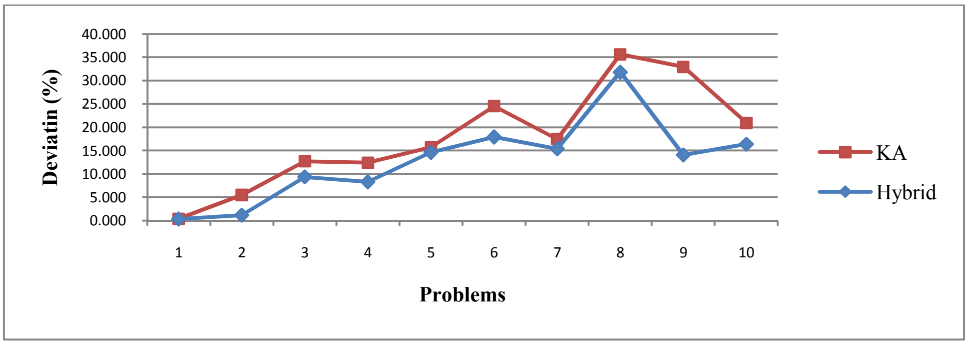

Figure 2: Comparisons of KA and KA-GA Hybrid according to the deviations of means from optimums

When the table is examined, the iterated solution improvement algorithm, KA, which is the first implementation of TSP, gives promising results. By itself, the development of the algorithm and parallel version of it can give better results. It is considered that; with hybrid system how much improvement of the results that obtained from KA. The result of the KA was sent to initial population of the hybrid algorithm. Looking at the results of the hybrid algorithm, it has better results in average values (Figure 2). The KA gives satisfying results when the problem size is large enough. The KA can provide good starting points for population-based algorithms or it can be used as a local search method.

This study has been motivated us for the development of the KA for TSP and similar problems. Can be used on its own or examined as a hybrid with different ISI and IPI methods. Since it works fast, the algorithm can be used easily as a local search method. Future studies planned to develop the descent and jump procedures and improve the duration of the searches. And then the developed algorithms will be used as local search method for solving symmetric TSP.

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