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by Admi Syarif

Implementation of Hybridized Genetic Algorithm for Fuzzy Traveling Salesman Problem

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Abstract: The Traveling Salesman Problem (TSP) is known as one of NP-complete optimization problems that has taken great interest of the researchers. The common objective is to determine route through some cities facilities in order to minimize travel distance. The classic TSP usually assumes that the travel costs are deterministic. In the real-world applications, due to the complexity of social and economic factors, it is often difficult to have deterministic value of travel costs (i.e. travel time). One way of handling such uncertainty in decision making is by introducing fuzzy programming approach.

Since TSP is also usually very large, huge research efforts have been devoted to develop heuristic algorithms for solving TSP. It has also been reported that Genetic Algorithm could give a good solution of TSP within reasonable time.

In this paper, we consider a more realistic model called fuzzy TSP. By assuming that the travel costs between cities are represented by triangular fuzzy number, we examine how the route should be designed. We develop a GA hybridized with local approach to solve the problem. Several numerical experiments are done to show the effectiveness of the proposed method.

Keywords: Fuzzy number, Logistic, Traveling Salesman Problem, Genetic Algorithm, Local Search

I. Introduction

With the development of modern society, engineering design becomes an important part human being's life. How to solve the problems effectively and efficiently will be a great research issue in this century or even further future.

Since it was introduced by Holland (1975), Genetic Algorithm (GA) has been proven to be a valid and robust alternative in optimization fields (Goldberg, 1989; Davis, 1991). GA has been widely and sucessfully used in different area of appications engineering, finance, economics, agriculture, business and so on (Gen and Cheng, 2000; Michalewicz, 1994). For some specific optimization problems, however, we need more efforts to obtain an improvement of GA performance. It includes to combine some local search techniques into GA (Syarif, Yun and Gen, 2002; Syarif and Gen, 2003).

The Traveling Salesman problem refers to a special class of combinatorial optimization problems. Though it is not so clear who first introduced TSP, it has been very popular and taken a great attention of researchers since 1954 (Dantzig, Fulkerson and Johnson; 1954). It has been applied for various real world applications. The classical TSP is usually stated as a problem of finding the shortest possible tour through N "cities" so that each city is only visited at once. It seems to very easy to say, however, for large size problems, it is very difficult to solve. It belongs to the class to NP-Complete problems and cannot be solved exactly in polynomial time (Aarth and Lenstra, 1997). Thus, Solving TSP optimally would take to long and normally one would uses approximation algorithm or heuristic algorithms (Dorigo and Gambardella, 1997; Johnson and McGeoch, 2002). In our previous work, we also have implemanted GA approach for solving TSP (Syarif, Wamiliana and Yasir, 2007).

In real world applications, moreover, we often have more complex of social and economic factors that need to be considered. It includes the difficulty to determine the proper value of travel cost or travel time between cities. One way of handling such uncertainty in decision making is by introducing fuzzy programming approach (Gen and Cheng, 1997).

In this paper, we consider TSP with fuzzy coefficient (fTSP). We represent the travel time between the city by using triangular fuzzy nmber. Our major efforts in this work include the development of GA method and adopt fuzzy ranking technique for handing the objective functions and fuzziness. Numerical experiment results are presented to demonstrate the effectiveness of the proposed method.

II. Mathematical model

In this section, we shall present a comprehensive mathematical model of fuzzy TSP as follows:

Let

$$x_{i,j}\begin{cases} =1 \text{ if the route from citi } i \text{ to } j \text{ is taken} \\ =0 \text{ otherwise;} \end{cases}$$

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$$\min \quad z(x)=\sum_{i=1}^{n}\sum_{j=1}^{n}\tilde{t}_{i,j}x_{i,j}\,, \quad i\neq j \qquad (1)$$

$$\text{s,t.} \quad \sum_{i=1;\,i\neq j}^{n} x_{i,j} = 1, j=1,2,\ldots,n \qquad (2)$$

$$\sum_{j=1;\,j\neq i}^{n} x_{i,j} = 1, \quad i=1,2,\ldots,n \qquad (3)$$

where n is the number of cities. $\tilde{t}_{i,j}$ is a triangular fuzzy number representing travel time between the city i to city j

In the above model, the objective function captures the total traveling time or total routing cost. The constraint (2) and (3) ensure that each city is only visited at once.

III. Design of the algorithm

1. Ranking Fuzzy numbers

As stated earlier, in this paper, we consider TSP in which the cost values are represented as fuzzy number (triangular fuzzy number) (Gen and Cheng, 1997). A triangular fuzzy number $\tilde{A}$ used in this paper is denoted by (a_1, a_2, a_3) where a_1, a_2, a_3 are real numbers. Its membership function $\mu_{\tilde{A}}$ is given as follows (See also Figure 1 for the illustration of this membership function):

$$\mu_{\tilde{A}}(x)=\begin{cases}(x-a_1)/(a_2-a_1), a_1\leq x\leq a_2\\(x-a_3)/(a_2-a_3), a_2\leq x\leq a_3\\0 \quad otherwise\end{cases}$$

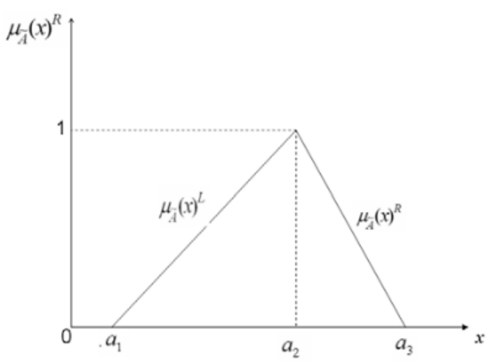


Figure 1. The membership function

When considering the optimization problem that its coefficients are represented with fuzzy numbers, the objective values of the problem will also be fuzzy numbers. One way to handling fuzzyness is the ranking fuzzy numbers with integral value technique proposed by Liou and Wang (1992). The basic concept of this technique is to rank the fuzzy numbers based on its total integral value. The left and right integral values are used to reflect the pessimistic and optimistic viewpoint of decision maker respectively. The total integral value is the n computed based on this degree of optimism and each objective function values. A parameter $\alpha \in [0,1]$ is given to adjust the degree of optimism.

Since it is clear from the above membership function that the left membership function $\mu_{\tilde{A}}(x)^L$ is continuous and strictly increasing, its inverse function $g_{\tilde{A}}(x)^L$ would exist and continuous on interval [0,1]. Thus it would be integrable on that interval. Similarly for the right membership function $\mu_{\tilde{A}}(x)^R$. Both the left and right integral values can be computed as follows:

$$I\left(\tilde{A}\right)^L = \int_0^1 g_{\tilde{A}}(x)^L dy = \frac{1}{2}(a_1+a_2)$$

$$I\left(\tilde{A}\right)^R = \int_0^1 g_{\tilde{A}}(x)^R dy = \frac{1}{2}(a_2+a_3)$$

Thus, the total integral value for triangular fuzzy number $\tilde{A}$ is

$$I_T^{\alpha}\left(\tilde{A}\right)=\alpha I\left(\tilde{A}\right)^R+(1-\alpha)I\left(\tilde{A}\right)^L$$
$$=\frac{1}{2}\left[\alpha\, a_3+a_2+(1-\alpha)a_1\right]$$

2. Genetic Algorithm For Fuzzy TSP

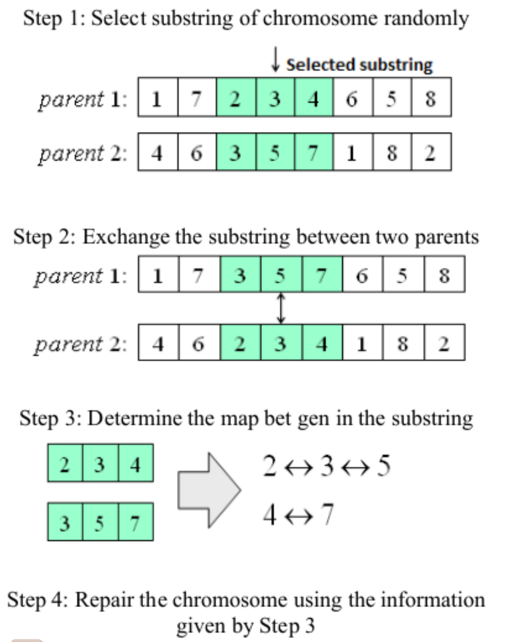
2.1. Chromosome representation

It is well known that the success of GA depends on several factors including an efficient design of the chromosome, genetic operator and so on. For TSP, one of the classical chromosome representations that can be used is permutation representation. Each chromosome represents the tour that is developed. An important issue here is how to generate chromosome that would bring us to a good solution. Instead of using random algorithm, in this research, we adopt Nearest-Neighborhood (NN) algorithm that is known to be better tour construction procedure. The NN algorithm is done by first selecting a node randomly. The next node in the tour is selected by selecting a node with nearest distance.

2.2. Genetic Operation

Crossover:

We employed **PMX** operation. This type of crossover is accomplished by selecting two parents of solutions and randomly taking a component from one parent to form the corresponding component of the offspring (Goldberg dan Lingle, 1985.). The procedure of PMX is given as follows:



Mutation:
To increase the variability of the population, mutation operation is done. We used here inversion mutation that can guarantee to generate feasible chromosome when the parents are feasible (Gen and Cheng, 1997).

Evaluation and Selection:
In our GA implementation, the evaluaton is done by calculating fuzzy objective for a given alpha value. We adopt the elitist selection strategy to keep the best chromosome from the current generation to the next generation.

2.3 Local Search

In order to obtain a good solution, we include local search techniques called *2-opt* into our GA process. this algorithm based on the idea that a good tour must not have crossing arcs. Thus, it is designed to omit the crossing arc in tour. The tour improvent is done by checking the following situation:

$$t(a, next\ (a)) + t(b, next\ (b)) > t(next\ (a), next\ (b)) + t(a, b). \tag{4}$$

As an example, consider the tour given in Figure 2. It is clear that arc (3,9) crosses arc (4,10). and $t(3,9) + t(4,10) > t(3,4) + t(9,10)$. Thus using *2-opt* algirthm we get a better tour as given in Figure 3.

IV. Numerical Experiment

In order to show its effectiveness, the proposed GA approach has been implemented in visual C language. Numerical experiments are done by modifying two benchmark test problems (mod-kroa150 and mod-eil76) given in the literatiure (Reinelt, 1991). The coefficients of the objectives are represented as triangular fuzzy numbers. Those represent three different speeeds (30 km/hour, 50 km/hour and 70 km/hour). We fixed the GA parameter as follows: crossover probability $p_C = 0.4$ and mutation probability $p_M = 0.2$, pop_size = 20 and max_gen =1000.

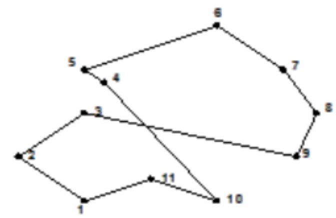


Figure 2. Tour with crossing arcs

Figure 3. Improved tour with *2-opt*

For our numerical experiments, we run our program by varying the values of α between 0 and 1. These values represent different degree of optimism. The results of our experiments are summarized in Table 1. For $\alpha = 0.5$, the heuristic solution for those test problems can be seen in Figure 4. The results show that the smallest objective value can be obtained when we determine the problem based on optimistic degree ($\alpha = 0$). On the other hand, the highest objective function value is when based on the pessimistic degree ($\alpha = 1$). Thus with this situation, the decision makers can determine the range of objective value based on his/her degree of optimism. This would be very important for decision support system in the real world applications.

V. Conclusion

In this paper, we consider a TSP with fuzzy coefficient. We develop a Genetic Algorithm (GA) approach to find the best heuristic solution to the problem. The proposed method adopt the concept of the ranking fuzzy numbers with integral value for the evaluation. With this technique, the decision maker can determine his/her decision by giving flexible value for the degree of optimism. The experimental results show the effectiness of the proposed method. Thus this technique would be suitable for decision support system.

Table 1. Computational results

	Alpha										
Test Problem	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
mod-kroa150	455,41	494,39	518,83	522,09	556,59	581,52	606,89	632,25	675,03	682,97	729,43
mod-eil76	10,29	10,71	11,56	11,84	11,99	12,89	13,65	14,29	14,86	16,01	16,6

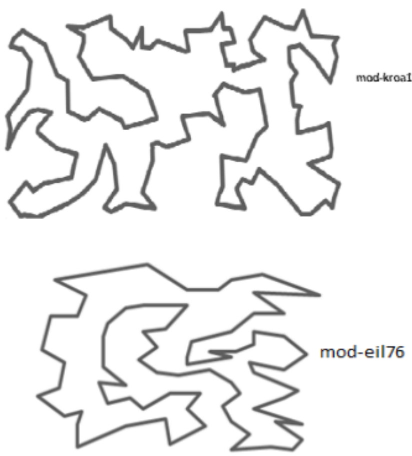


Figure 4 The best heuristic route for mod-kroa150 and mod-eil76 ($\alpha = 0.5$).

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