2004 International Symposium on Nonlinear
Theory and its Applications (NOLTA2004)
Fukuoka, Japan, Nov. 29 - Dec. 3, 2004

Proposal of Improved Method for Dynamic Traveling Salesman Problem

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Abstract—In this paper, several approximation methods for Dynamic Traveling Salesman Problem with the movement of cities are proposed. Those methods belong to construction method based on Nearest Neighbor method and our main aim is to pursue high-speed computational algorithm. Our simulation results in respect of the cost are near or equivalent to those using Nearest Neighbor method each time. And computational time can be kept to about two thirds of the worst solution.

1. Introduction

In analysis of physical phenomena, we have neglected differences from equilibrium states and approximated them to equilibrium states. However it has been clarified that we can not neglect their non-linearities in virtue of the advance of complex system science. Complex system science has been given us excellent explanation of order, disorder and several kinds of pattern formation in nature using statistical physics as an important leverage. Self-organization, mutual interaction and emergency which can been seen in these phenomena have given birth to the field of emergency science. Moreover they make a great contribution to the analysis of the mechanism of information processing of human brain. From the engineering aspect, their concepts have been already applied to data compression, computer graphics and so on. We might say complex system science achieved a firm footing in the world.

On the other hand, optimization problem as typified by operations research is very general problem, and it has a much broad range of applications. Its difficulty strongly depends on the configuration of imposed conditions, however most of them is static, that is, the condition of the problem will never change in general. In the case of variable condition, optimization problem becomes much more difficult than that in static case. In recent years, there increases dynamical motioning devices and their applications like mobile communication, car navigation system, communication using satellite and so on. Hence effective algorithms for dynamical problem are strongly required for the industrial reasons.

In this paper, we address Dynamic TSP with the movement of cities. Our main aim is to establish the optimization method for which the traveling cost will not become much higher and the computational time will stay within some given limit for practical use.

2. Traveling Salesman Problem

Traveling Salesman Problem(TSP) is the problem that how we can obtain the minimum way to visit the whole cities only once. It is one of the representative optimization problems and famous for its NP-complete property[1]. There are many industrial applications like transportation planning, task scheduling, VLSI circuit design and so on, and fast and high precision approximation method is strongly required. Hence several kinds of approximation methods have been proposed and applied to practical use so far.

Approximation methods can be roughly categorized into construction methods and improvement methods. The former is that we construct traveling route from the beginning and Nearest Neighbor(NN) method which is basis of our method belongs to this category. While the latter is that we improve the route somehow which has been obtained by another method, typically some construction method.

Though improvement methods make a point of its accuracy in general, they take huge computational time. It depends on its purpose which method we select, however the accuracy is more important in case of static problem. In that case, we sacrifice computational time to some extent, and many methods based on repetitive learning like Genetic Algorithm(GA) and so on have already proposed and brought us some remarkable results. Especially optimal methods based on colony behavior of ants are actively pursued recently and it is called "Ant Colony Optimization(ACO)" and many studies have been done these few years[2]. We can regard it as one of the applications of multiagent system, that is the system in which mutual interaction among independent agents is dominant, therefore the study of TSP seems to enter a new phase.

3. Dynamic Traveling Salesman Problem

3.1. Definition

In an ordinal TSP, each city is fixed and the algorithm for finding the traveling route is not dependent on time, hence we can use enough time to find optimal solution. However, there are some cases which can not be considered as time independent. One of them is the case that some cities are inserted or deleted, and the other case is that all or some part of the cities are moving with time. Of course, the

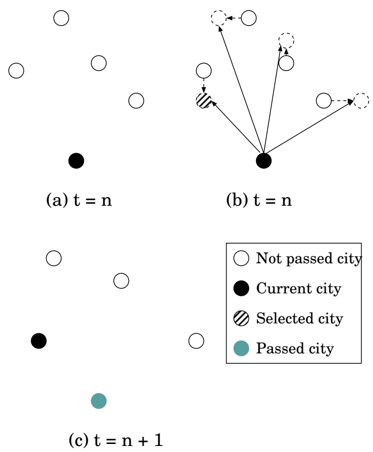

Figure 1: Method of discretization of time in DTSP. We set forward time clock after the movement to the next city.

movement is allowed to be contiguous or discrete. In the above two cases, insertion/deletion or moving, the states of cities can be considered to be dynamic and time dependent, and we call them Dynamic Traveling Salesman Problem(DTSP).

3.2. Applications and Approaches

There are several kinds of applications of DTSP. According to recent development of communication technology, demand for DTSP has become larger. Though the most attractive subject now is network routing problem, their applications are not restricted to engineering field. One simple but interesting example in sports is passing a ball among moving ball game players.

In the case of inserted/deleted city, since the number of cities changes but their position will not change, the problem can be considered as natural extension of static TSP. Hence similar approach like in the ordinal TSP can be proceeded, and some approaches have begun these years, e.g. the analysis using ACO[3][4].

But in the movement case, the problem becomes much more difficult because the position of cities will change. Such problems belong to so-called "Open Problems" like free boundary problem in PDE. Not only the case that the movement of cities is obvious function of time but also the case which the position of each city is ambiguous are included. For the ambiguous case, GA approach has been already done by Yoshida et al.[5]. Though our main subject is the former case, we stop the time during searching a next city and assume intervals for moving to the next are always constant(Fig.1). Hence our problem might be called quasi-TSP.

4. Simulation Method

In this paper, we propose not improvement but construction methods. It is because our main concern is under the situation that the position of cities changes dynamically, and we do not have enough time to obtain adequate solution using improvement methods. According to the limit of time, we improve fast NN method and propose more suitable method for dynamical problem. Here we suppose that not all the cities but a part of them are always moving. The moving direction is vertical or horizontal, and it is constant or variable. The velocity is random and we fix the position of cities after the visit. The abstract of our simulation is as follows.

1. We distribute all the cities randomly.
2. For the above city distribution we create a traveling path using Nearest Neighbor(NN) method which we select the nearest city each time and obtain the total cost.
3. We select some cities and change their position with time. Their velocities changes randomly and moving direction of each city is constant or random.
4. We obtain the new path and cost using NN method each time.
5. We calculate the cost using the original path(Worst cost solution) for comparison.
6. We apply our improved methods described below and obtain the new path and cost.
7. We compare our those results.

We propose several improved methods for the above procedure. Here we explain them briefly as follows.

Method 1:
As shown in Fig.2, we nominate three nearest cities(a, b, c) from the present city at first. Next we compare current velocities of them. The higher the velocity is, the farther it might to recede from there if we let it be. Then it becomes to have a serious influence upon its total cost, hence we selected that city(C) for the next.

Method 2:
It takes too much time with method 1 because we have to calculate all the distances from the present city to another. We nominate only several cities within some constant neighborhood, then select a city like method 1. In this method it might happens that nearer city is not selected. Moreover it is difficult to select a proper and non-empty neighborhood.

Method 3:
Since the exact calculation of the distance between two

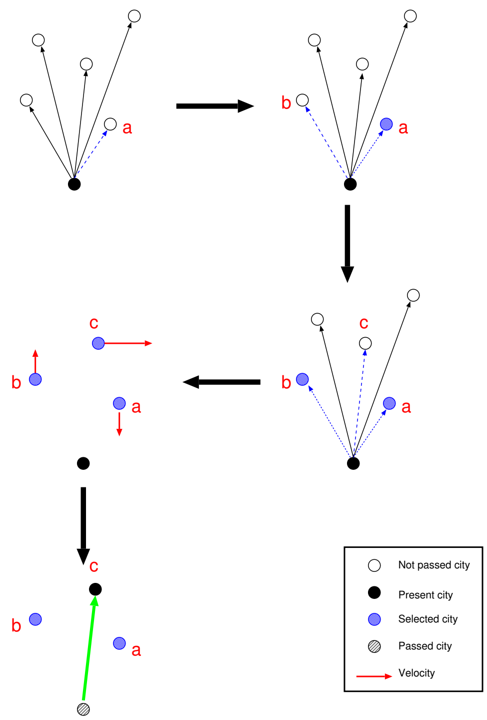

Figure 2: Method of selecting the next city. We nominate three candidates and select the one which is moving fastest.

cities takes slightly much time, we substitute it with the difference of their coordinates($\Delta x + \Delta y$) and then we apply method 1.

5. Results and Discussion

We show our results concerning about the cost in Fig.3 and Fig.4. The former is the case the moving direction of cities is constant and the latter is random case. For the comparison, results of without improved procedure(worst solution) and applying NN method each time are also shown in these figures. The former gives almost worst cost and the latter gives the worst computational time, nevertheless it gives reasonable cost solution. With method 2, the possibility that nearer city might not be selected gives a bad influence and comes to a bad result. On the other hand, it gives similar result as the method we use NN method each time with method 1 and 3. In these methods we select one city from three candidates though, the influence of the possibility that nearer city might not be selected is small. Though it is anticipated the accuracy becomes worse if the change of moving direction of cities is random, its influence seems to be small.

In respect of the computational time, we regard the worst case we apply NN method each time as the standard of estimation. We need a faster method than the above standard at least. Though method 1 takes almost similar time, method 2 and 3 takes only about two thirds of the worst.

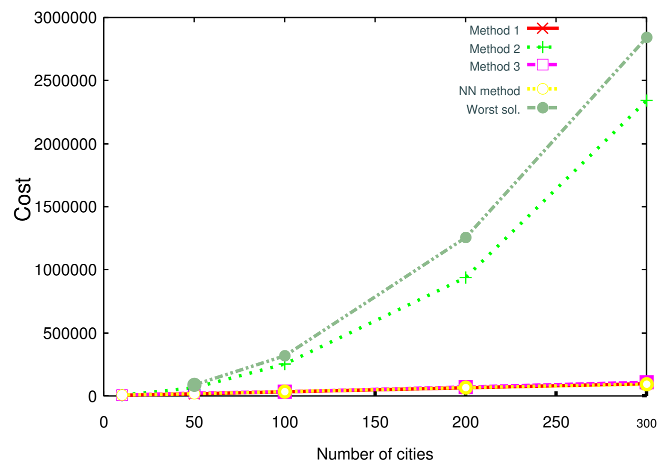

Figure 3: The total cost of traveling all the path. Moving direction of each city is constant.

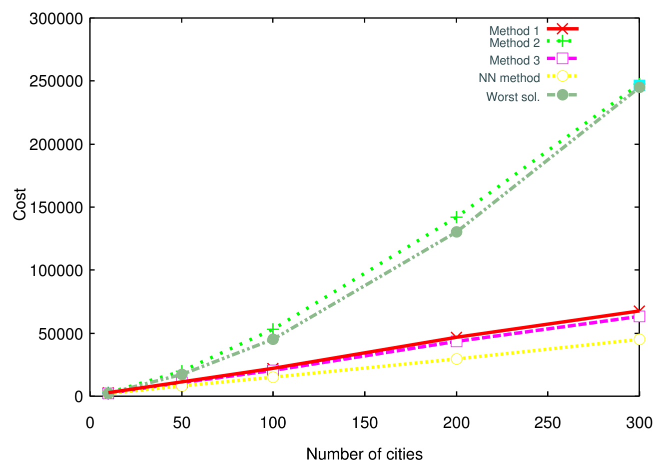

Figure 4: The total cost of traveling all the path. Moving direction of each city is random.

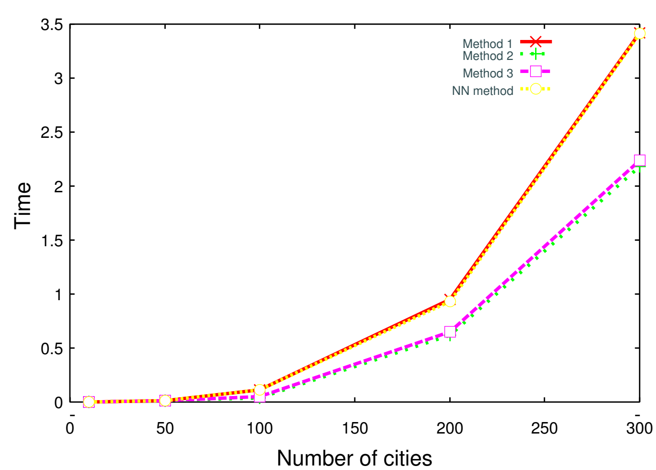

Figure 5: The computational time of calculation.

From these results, though we can not obtain better results than NN method in respect of the cost, computational time can be reduced. Since all objects are moving, the reduction of computational time is considered to be more essential for its application.

6. Summary

We proposed several approximation methods for Dynamic TSP with the movement of cities. Since our methods belong to construction method based on NN method, we can expect to obtain fast approximation solution. We could obtain reasonable results near or equivalent to those using NN method each time in respect of the cost. And we succeeded in keeping the computation time to about two thirds of worst solution. As future problem, we adopt prospects of movement of each city and improve how to select next city, then we obtain better results and take realistic situation into consideration to our method.

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