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SIMULATED ANNEALING APPROACH FOR SOLVING A TIME DEPENDENT ORIENTEERING PROBLEM

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ABSTRACT

This paper aims to deal with the Time-Dependent Orienteering Problem (TDOP) which is a specific type of the Orienteering Problem in which a real life application is modelled that suggests an efficient tour plan for Istanbul. In this specific problem, the traveling time between two points relies on the tour starting time. The problem is solved with a simulated annealing approach which is a heuristic method and provides a tour route with a limited time while considering the traffic in the city. This TDOP problem deals with dynamic initial points while intending to choose the route with high score. Visiting points in Istanbul and various initial points are considered to solve this problem.

KEYWORDS: Itinerary planning, simulated annealing, metaheuristic methods, time dependent orienteering problem

1. INTRODUCTION

The Orienteering Problem (OP) term came from the sport of orienteering which is established upon the concept of the individual sport usually played in a mountainous or heavily forested area .In this game, competitors begin the tour with selected point which is the starting point attempt to browse as many checkpoints as possible and come back to the control point in the given limited time period. If the agent is not able to return to the beginning point by the expected time , he is got out of the game so it is his duty to arrange his path properly to maximize the total point numbers and returns before the time limitation is completed . Every single point has a score and the aim is to maximize the overall obtained score. [1]. The leading purpose is to find a path by going to as many point as achievable also try to gather maximum score in a assigned time budget. The initial point and the end point assumed same and fixed. Numerous OP versions are explained in the various literatures like [2]: selective traveling salesperson problem [3]), home fuel delivery problem [4], single-ring design problem [5], and mobile tourist guide [6]. The Time-Dependent Orienteering Problem (TDOP) has studied in paper which is a generalization of OP. In the pure OP, the time changes on the network are not evaluated; although, in some networks, the path between two points actually relies upon the network |attributes, like as congestion, etc., which will certainly alter the travel time between two points [2]. The desired result of this study is to offer a route to visit Istanbul by considering departure time and waiting times in each place. The purpose is to improve the overall score of the tourist attractions within the available touring duration. We create a metaheuristic based on Simulated annealing (SA) concepts, which is a is a random-search method exploiting an analogy between the way in which a metal cools and freezes into a minimum energy crystalline structure (the annealing process) and the search for a minimum in a more general system; it forms the basis of an optimization method for combinatorial and other problems [7]. In this study, this approach was tried using the real world data obtained from Istanbul.

Literature Review

OP is also recognized as the selective traveling salesperson problem [8] or traveling salesman problem with profits [9]. A complete and detailed review of OP can be revealed in work by Vansteenwegen et al [24]. Tsiligirides et al is the basic to present an overall definition of the orienteering and formulate heuristic techniques founded on a Monte Carlo technique for the OP [3]. Golden et al produced a new method based on four principles: center of gravity, randomness, sub gravity, and learning [11]. Varied metaheuristics for solving the OP have been suggested by studies, such as Tabu Search [12], Genetic Algorithm (GA) [13]. TDOP is type of OP by considering time changes in the network. The traveling time from one point to another point changes relies on the initial time. It was suggested by Fomin et al [14], another work proposed ant colony system for solving TDOP [15]. Time-Dependent Team Orienteering Problem with Time Windows which started from the development of personalized electronic tourist guides by integrating the tourist planning problem and the use of public transportation, and two different techniques founded on Iterated Local Search are suggested to solve a set of test cases based on real data for the city of San Sebastian, Spain [16].

Also, our earlier work TDOP focused on solving the same problem by a modified genetic algorithm [17].

Time Dependent Orienteering Problem

The problem is known as time-dependent if the schedule of a tour depends on its beginning time in which the travel time between two point depends on the departure time at the initial point [14]. This special problem formulation makes it possible to deal with congestion related challenges in routing problems such as morning and evening peaks hours on the freeways or populated city center traffic situations [16-18].

Simulated Annealing (SA)

Simulated annealing is identified because of its analogy to the process of physical annealing with solids [19]. SA is a local search algorithm that finds out its idea in the physical annealing procedure analyzed in statistical mechanics [20]. SA algorithm repeats an iterative neighborhood generation routine and employs search directions that develops the objective function value. SA provides the opportunity to accept worse neighborhood solutions in order to escape from local minimum [21]. Simulated annealing could be formulated in the way of a local search algorithm. To make ease the discussion, suppose (S, f) as a combinatorial optimization problem and a neighborhood function N, simulated annealing outlined below. There are four main function in this algorithm; first INITIALIZE to develop a route as starting solution with initial values of the parameters C and L; GENERATE determines a solution from the neighborhood of the existing solution; CALCULATELENGTH and CALCULATECONTROL compute new values for the parameters L and C, a standard simulated annealing, has probability of moving to less fit states as well as taking improvements ,in order to escape from local minimum in larger values of C, more less fit states accepted; as c decreases, lower degenerations accepted and, with 0 value of C , no less fit states accepted at all. Simulated annealing, in comparison to iterative search, could escape from local minima while it utilizes the advantageous of iterative search. Taking less fit state is done by calculating the value of exp ((f (i) — f (j))/C). The speed of the algorithm is depend on parameters L_k and C_K with k = 0, 1… where L_k and C_K shows the values of L and k in iteration k of the algorithm [22].

Begin
INITIALIZE (i_{start}, C_o, L_o); **//Initialize solution**
k: =0;
i: = i_{start};
Repeat
For L: = 1 **to** L_k **do**
Begin **//Create neighborhood**
GENERATE (j from S_i);
If f (j) < f (i)
Then i: =j;
Else
If exp ($\frac{f(i)-f(j)}{ck}$) > **random** [0, 1) **then** i: = j **// Maxwell–Boltzmann distribution**
End;
k:=k + \;
CALCULATELENGTH *(L_k);*
CALCULATECONTROL (C_k)**;**
End;

Problem definition

In this problem, all visiting points has a Score that reveals the best way strongly the visitor desire to visit that point. For example, a visitor may put higher priority on going to a museum than on going to a shopping center. In this problem, visiting points are included historical places, museums and shopping centers with associated scores and times. In general the plan splits the total accessible time budget into two fundamental parts: traveling and visiting times. Hence the problem determines the route that visits a few of points for the duration available time span which provide the most visitor satisfaction As a way to manage this problem, this thesis presented a metaheuristics solution based on SA that designs an itinerary for a given time span; e.g., an 8-hour program, that starts a tour and visit as many high priority points as possible over time budget and return to initial point before exceeding the available time period. Therefore, in order to manage this particular problem, 4 hotels in various parts of Istanbul are considered as initial points, 18 points are assumed.

Solution method

The SA implementation requires [23]:

1. State space with fitness measure
2. Graph on the state space
3. Temperature schedule

State space: each case of the TDOP has a set of cities. So the search space is consisting of city sets. The fitness value is simply calculated by the sum of each point's score. The goal is to find a route with the highest fitness.

Graph: The network topology of the graph is a one-dimensional graph and totally connected graph. By considering the satellite view of Istanbul on Google Maps, it appears that there are alternative routes for any two places. In order to generate the more realistic results for this problem, real distances, not Euclidean distances, were used.

Temperature: The key to SA's technique find global optimums, and what distinguishes it from simple hill-climbing algorithms, is that at each iteration it has a probability of moving to less fit states in order to escape from local minimums.

Results

Considering all the results for 5 nodes it shows that by increasing time changes happen to almost all initial points (Table 1); in the case of 5 nodes the best solution both with time budget 480 minutes and 540 minutes is starting from Besiktas by considering the highest score and minimum total time.

Table 1. (5 nodes; Departure time=8)

Initial point	Time budget =480 min	Time budget =540 min
Taksim	BEST Solution = 7 12 11 8 4 BEST Fitness = 390 BEST Time = 479 time = 1.0745 sec	BEST Solution = 7 3 15 2 12 BEST Fitness = 415 BEST Time = 530 time = 0.61192 sec
Besiktas	BEST Solution = 5 8 3 2 7 BEST Fitness = 400 BEST Time = 460 time = 1.8247 sec	**BEST Solution = 11 3 7 2 8** **BEST Fitness = 425** **BEST Time = 516** **time = 0.7827 sec (Depicted in Figure 1)**
Maslak	BEST Solution = 2 9 19 3 8 BEST Fitness = 385 BEST Time = 449 time = 0.83229 sec	BEST Solution = 7 10 12 2 16 BEST Fitness = 385 BEST Time = 472 time = 0.82924 sec
Sultnahmed	BEST Solution = 12 8 9 2 16	BEST Solution = 7 12 11 3 15 BEST Fitness = 390

	BEST Fitness = 385 BEST Time = 411 time = 0.55691 sec	BEST Time = 504 time = 0.9373 sec

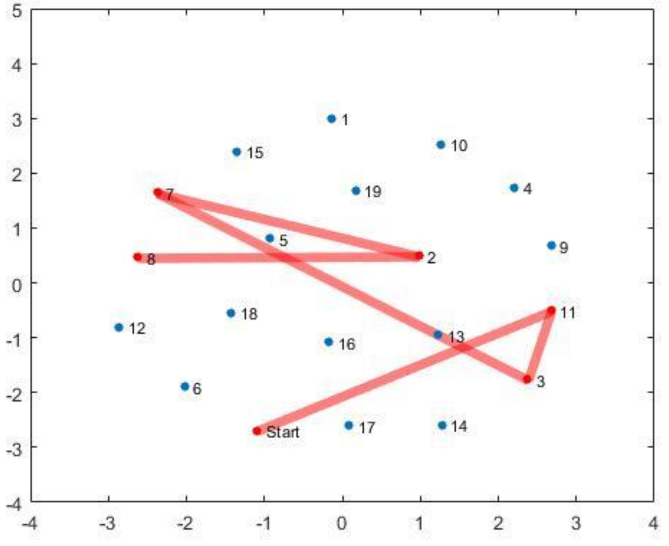

Figure 1. Example for best solution in 5 nodes

The results for 6 nodes demonstrate that any increase in time budget directly increases the path score (BEST FITNESS).In the case of 6 nodes (Tables 2) the best solution with time budget 480 minutes is Maslak and 540 minutes is starting from Besiktas just as it was in 5 nodes case.

Table 2. (6 nodes; Departure time=8)

Initial point	Time budget=480 min	Time budget=540 min
Taksim	BEST Solution = 10 8 9 15 5 7 BEST Fitness = 410 BEST Time = 455 time = 0.58733 sec	BEST Solution = 7 12 10 5 8 9 BEST Fitness = 435 BEST Time = 442 time = 0.56421 sec

Besiktas	BEST Solution = 2 18 19 9 8 10 BEST Fitness = 420 BEST Time = 453 time = 0.85151 sec	**BEST Solution = 8 3 2 17 4 9** **BEST Fitness = 465** **BEST Time = 527** **time = 0.64509 sec (Depicted in Figure 2)**
Maslak	BEST Solution = 12 18 7 10 8 9 BEST Fitness = 440 BEST Time = 460 time = 1.8571 sec	BEST Solution = 4 8 9 19 3 2 BEST Fitness = 455 BEST Time = 538 time = 0.89069 sec
Sultnahmed	BEST Solution = 9 8 10 12 19 4 BEST Fitness = 420 BEST Time = 453 time = 0.67563 sec	BEST Solution = 8 12 18 4 17 2 BEST Fitness = 445 BEST Time = 518 time = 0.70446 sec

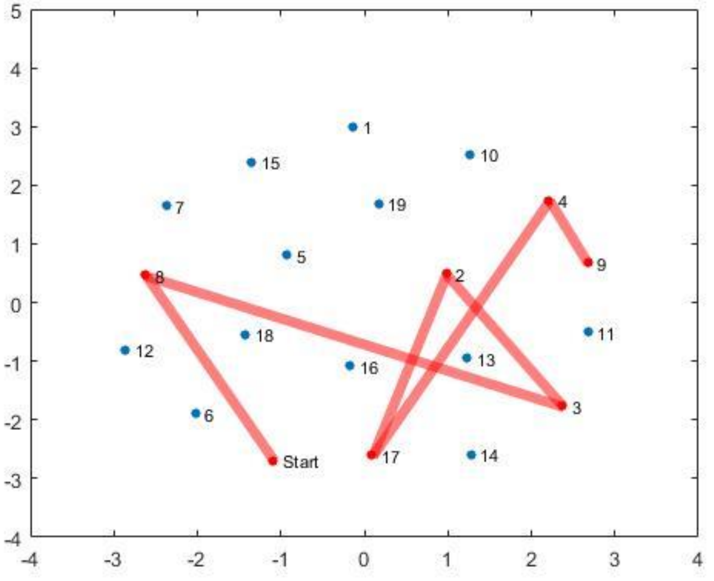

Figure 2. Example for best solution in 6 nodes

As presented above, it is clear that, by increasing time budget for one hour in all cases, total score is improved. The same improvement happens in 7 node point (Table 3); in the case of 7 nodes the best solution in time budget 480 minutes are both Sultanahmed and Besiktas starting points and in 540 minutes time budget the best route is starting from Sultanahmed.

Table 3. (7 nodes; Departure time=8)

Initial point	Time budget =480 min	Time budget=540 min
Taksim	BEST Solution = 17 9 8 10 12 16 18 BEST Fitness = 465 BEST Time = 478 time = 1.2348 sec	BEST Solution = 3 10 16 8 4 18 9 BEST Fitness = 485 BEST Time = 528 time = 0.85778 sec
Besiktas	BEST Solution = 18 16 3 9 8 10 17 BEST Fitness = 470 BEST Time = 470 time = 2.5925 sec	BEST Solution = 16 19 18 3 7 10 8 BEST Fitness = 470 BEST Time = 514 time = 0.84228 sec
Maslak	BEST Solution = 16 10 9 17 18 5 8 BEST Fitness = 430 BEST Time = 471 time = 2.6528 sec	BEST Solution = 15 12 9 3 10 18 16 BEST Fitness = 480 BEST Time = 535 time = 0.69988 sec
Sultnahmed	BEST Solution = 10 18 16 8 7 9 5 BEST Fitness = 455 BEST Time = 470 time = 1.9082 sec	**BEST Solution = 10 8 19 7 3 9 5** **BEST Fitness = 485** **BEST Time = 523** **time = 0.59392 sec (Depicted in Figure 3)**

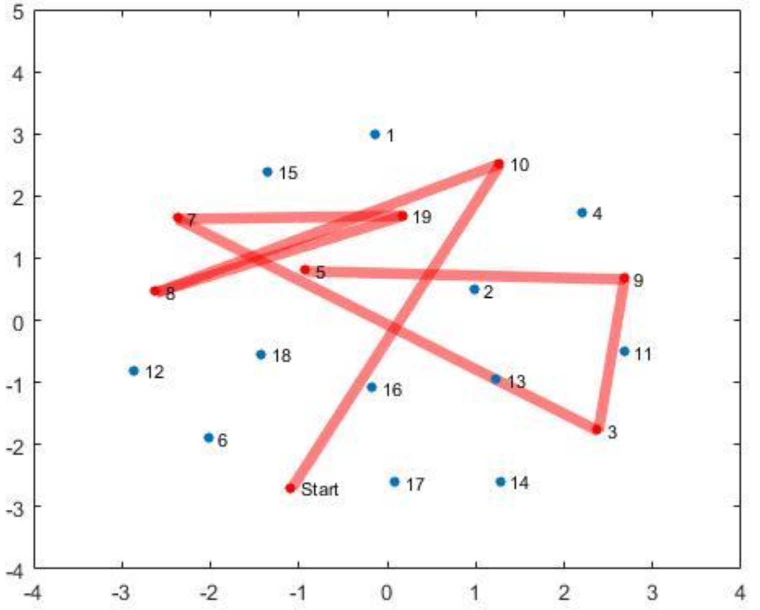

Figure 3 Example for best solution in 7 nodes

So as a result it is obvious that time budget can directly affect the path score. But in general there is no obvious difference in scores in different time budgets. So by increasing node number we can visit more places in the limited time also some visiting points have a high score, but their long visiting time may cause their removal from the path. Therefore, by increasing time budget, path will add some nodes with high score in spite of their long visiting time to the optimal paths and as a result, the amount of score changes.

Conclusion

In this paper, a metaheuristic algorithm based on SA concept applied to solve a TDOP and plan a tour solution for visitors. The algorithm was applied and tested in a real life case. The final results of this research can be applied in creating a tour plan for visitors. Further researches may be performed by applying other metaheuristic methods such as Genetic algorithm and Ant colony algorithm and compare the metaheuristics performance. Applying a time window for visiting points which can only be visited in a particular hours of a day such as museums and gathering online traffic data for tour planning would improve this research.

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