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A GENETIC ALGORITHM-BASED APPROACH TO THE TOUR PLANNING WITH STAYING TIME-DEPENDENT SATISFACTIONS

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Abstract. *The objective of this paper is to find a tour planning with which all utilities could be maximally used within the given time limits. The problem considered in the paper is similar to the traditional TSP (Travelling Salesman Problem), but it is believed that there exist many differences between those two problems: some of the candidate nodes can be chosen, and the staying times for the nodes are changeable and affect the satisfaction of their utilities. A genetic algorithm-based heuristic approach to the tour planning problem for maximizing tourist's satisfaction is suggested in the paper and comparisons with several heuristic approaches are also made. A numerical example is provided to illustrate the solution procedures for verifying its appropriateness.*
Keywords: Tour planning, Tourist, Staying time, Genetic algorithm, Traveling salesman problem, Satisfaction

1. **Introduction.** Tourism becomes the main activity for people to spend their leisure time. Tourists pursue more experiences and satisfaction during the tour. Easy access for tourists presents significant travel growth to various destinations and cities including to Asia and the Pacific region. In 2017, according to the data from the United Nations World Tourism Organization (UNWTO), Asia and the Pacific is the second most-visited region in the world. The data from UNWTO showed that Europe region led with 671 million (+8%) international tourist arrivals, followed by Asia and the Pacific with (+6%) 324 million. Within Asia and the Pacific region, China has developed rapidly into the top leader in global tourism. Chinese outbound tourist market has encouraged tourism flows from the region [1].

The development of information communication and technologies (ICT) enables tourists to reach online information and to arrange their personal tour planning by themselves. At the same time, free independent traveller (FIT) or self-planned tourism has increasingly become the main trend. In the vast ocean of information, users often need to spend a lot of time and efforts planning their trips, causing a lot of unnecessary troubles and wastes. There is also a lack of information on tourist attractions which lead to an increase of transfer time, low satisfaction, and a decrease of free time. Tourism planning is an important part of achieving tourist satisfaction. Therefore, planning an optimal tourist route is necessary.

Abbaspour and Samadzadegan [2] developed a time-dependent personal tour planning and scheduling in a multimodal shortest path subroutine with a specific period. They applied a genetic algorithm for determining the sequence of attractive destinations. Zhu et al. [3] formulated the tour planning problem in general, which mixed integer linear programming and used a heuristic algorithms method based on the idea of local search. Hasuike et al. [4-6] proposed time-expanded network (TEN) to find an optimal solution.

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They are considering the time durations for sightseeing. Awal et al. [7] established a hybrid approach to plan itinerary for tourists without focusing on tourist satisfaction and staying time. Sherestha [8] used nearest neighbor algorithms to develop a support model for optimization of tour time without considering satisfaction of tourist utility.

However, none of the existing research has mentioned anything about the length of stay and tourist's satisfaction, and utility scores for any given tourist attraction that is designated. Therefore, the purpose of this study is to find a tourist route with the highest utility score, which permits the shortest transfer time between the most popular attractions in a city within a limited time period. The use of genetic algorithm (GA) and python has helped achieve the best results. This study provides practical guidance on the sightseeing in a city and can be applied in real life. This paper is organized as follows. Section 2 points the problem statement, Section 3 provides the solution procedure, we introduce genetic algoritihm as search and optimization techniques to find solution, Section 4 includes the numerical example and Section 5 presents the conclusion and future research area.

2. **Problem Statement.** Travelling Salesman Problem (TSP) is one of the well-known problems in the several research fields. This study is similar to TSP, but has some different attributes: some of candidate nodes can be chosen and the staying times for each node are changeable and affect the satisfaction for tourist. What is pursued is a high utility score rather than the least cost or the shortest route. Figure 1 shows an example of a tour sequence in Busan, Korea. The objective is to find a tourist route with the maximum utility. The decision variables consist of two components, namely, the sequencing of tourist attractions and the staying times. The heuristic algorithm based on genetic algorithm includes genetic algorithm and the heuristic for repairing which considers rescheduling the remaining time. The utility score for each tourist attraction is calculated as the satisfaction utility percentage corresponding to the staying time multiplied by the recommendation score of the attraction. Also, if the total sightseeing time is stipulated as

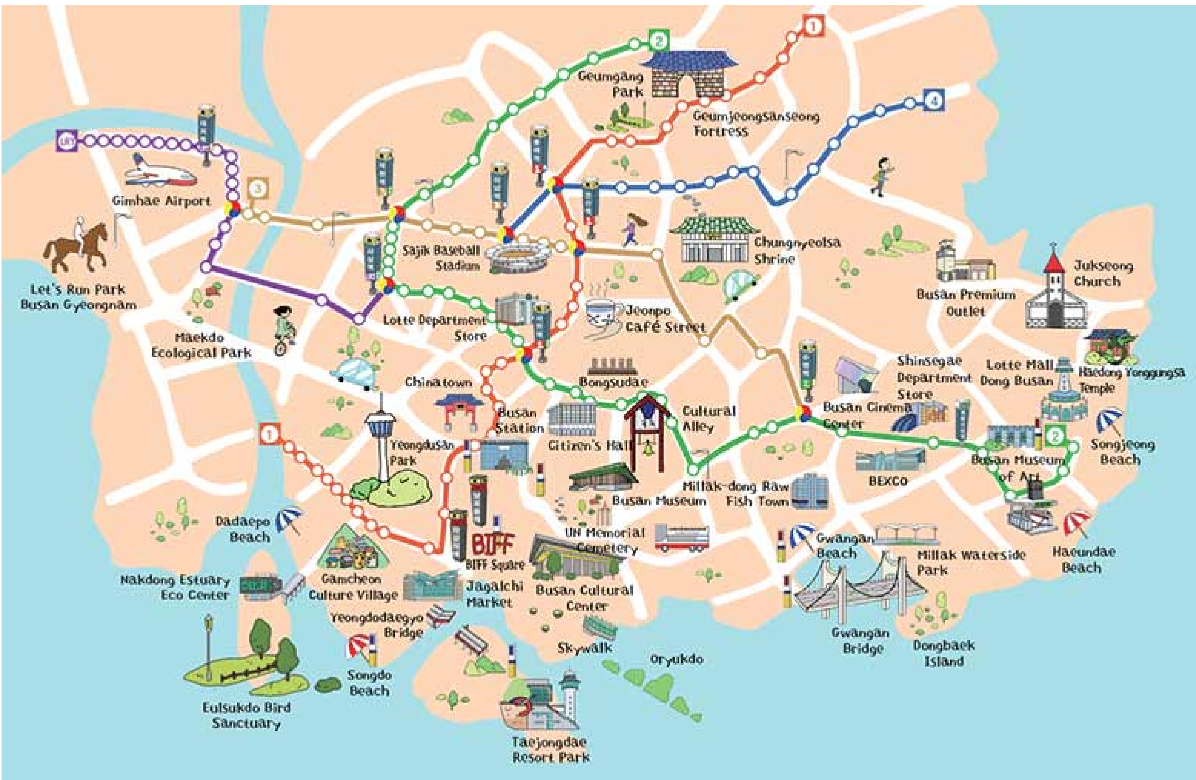

Figure 1. An example of tour sequence in Busan, Korea

600 minutes, the sum of the total traveling time and the sightseeing time cannot exceed 600 minutes.

3. **Solution Procedure.** The genetic algorithm (GA) is applied in the solution procedure, which is a stochastic solution search procedure that is proven to be useful for solving combinatorial problems. First of all, parameters are set and the initial population is generated. Then the fitness function is set as the highest utility score. Figure 2 shows an example of chromosome representation, which consists of two components. The first one is an arbitrary order of the ten tourist attractions. The second one is the score for the level of satisfaction reflected by the length of staying time expressed in binary. Due to the time limit of 600 minutes, the route beyond 600 minutes will be automatically deleted.

2			**3**			**9**			**4**			**5**			**10**			**6**			**1**			**8**			**7**		
0	**1**	**1**	**1**	**0**	**1**	**0**	**0**	**0**	**1**	**1**	**1**	**0**	**1**	**1**	**1**	**0**	**1**	**0**	**1**	**0**	**0**	**0**	**1**	**1**	**1**	**0**	**0**	**0**	**0**

Figure 2. An example of chromosome representation

It is assumed that the level of satisfaction for the longest stay at all attractions is 100%, and the minimum level of satisfaction is 30%. Available combinations and corresponding chromosomes are shown in Table 1.

Table 1. Tour path and staying times for each attraction

2*2	2*1	1	Count	Satisfaction utility percentage	Remark
0	0	0	0	30%	Minimal staying time
0	0	1	1	40%	
0	1	0	2	50%	
0	1	1	3	60%	
1	0	0	4	70%	
1	0	1	5	80%	
1	1	0	6	90%	
1	1	1	7	100%	Maximal staying time

The staying time at various tourist attractions in between the shortest and longest stay can be arbitrarily selected, with the corresponding utility score ranging from 30% to 100%. From this, we can acquire the tourist satisfaction utility score which corresponds to the stay time. In this study, the genetic algorithm (GA) operators include order crossover (OX)/single-point crossover, insertion mutation/random mutation and roulette wheel selection. Two crossover methods were used such as OX for tourist attractions and single-point crossover for the staying time, respectively. Order crossover OX in Figure 3 is a kind of variation of PMX (partial-mapped crossover) with a different repairing procedure.

1) Select a substring from a parent at random.
2) Produce a proto-child by copying the substring into the corresponding position of it.
3) Delete the tourist attractions which are already in the substring from the 2nd parent. The resulted sequence of tourist attractions contains the ones that the proto-child needs.
4) Place the tourist attractions into the unfixed positions of the proto-child from left to right according to the sequence to produce an offspring.

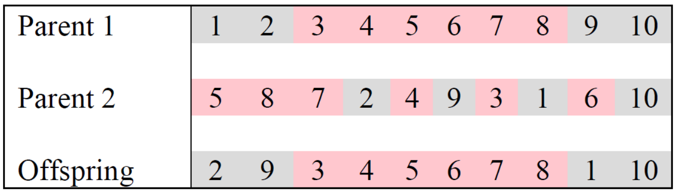

FIGURE 3. An example of OX

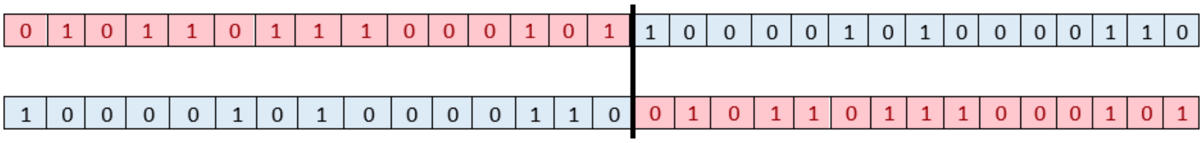

FIGURE 4. An example of single-point crossover

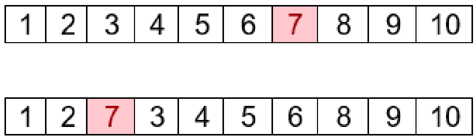

FIGURE 5. An example of insertion mutation

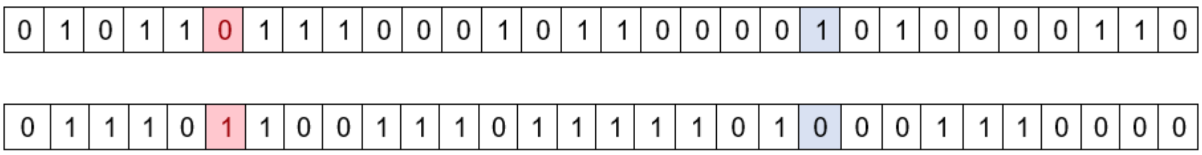

FIGURE 6. An example of random mutation

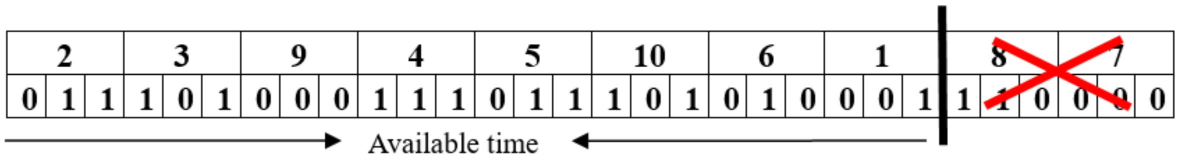

FIGURE 7. Repairing heuristic

The single-point crossover for staying time randomly selects one cut-point and exchanges the right parts of two parents to generate an offspring (See Figure 4).

The second mutation methods were also applied: insertion mutation for sequencing tourist attractions was used, which is shown in Figure 5.

And for the staying time genes, random mutation was applied, which is shown in Figure 6. It alters one or more genes with a probability equal to the mutation rate. When the gene is 1, it would be flipped into 0. And when the gene is 0, it would be flipped into 1.

As shown in Figure 7, chromosome is repaired considering the total planned time. Any itinerary arrangements beyond the total given time will have to be deleted so that the total amount of time spent on the itinerary equals the total given time. Remaining time is reallocated to some chosen attractions reflecting their scores and available times, simultaneously.

4. **Numerical Example.** An illustrative example is provided to explain the appropriateness of the suggested approach. As shown in Table 2, Busan is selected with many famous attractions. Ten attractions are recommended and their utility score is determined according to TripAdvisor. The airport has been designated as a starting point and the hotel as the last destination. The maximal staying time for each attraction is defined by a travel agent in Busan.

Table 2. Tourist attraction in Busan

No	Tourist attraction
0	Gimhae International Airport
1	Haeundae Beach
2	Gwangalli Beach
3	Gamcheon Culture Village
4	Boemoe Temple
5	Dongbaek Island
6	Taejongdae
7	Haedong Yonggng Tample
8	UN Memorial Cemetery
9	Jagalchi Market
10	BIFF Square
11	The Westin Chosun Busan (hotel)

The data were randomly generated in PHYTON with a time limit of 600 minutes and the route beyond the time limit was automatically deleted. The result in a genetic algorithm method is 39.8 as a highest total utility score. The best tourist route with the best total traveling time is shown in Figure 8.

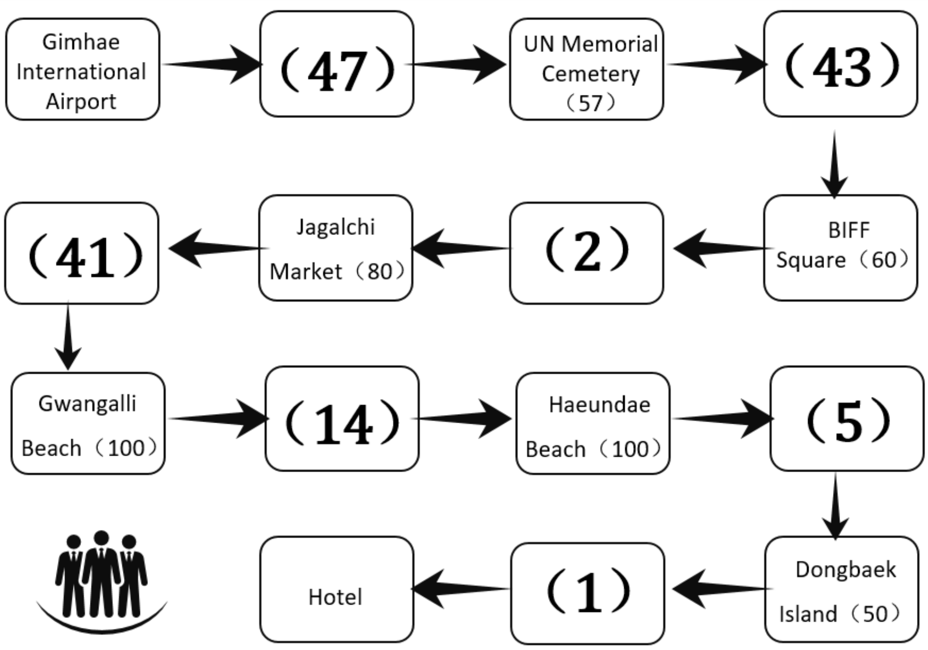

Figure 8. The best tourist route in GA

On the other hand, in the case that the highest utility score corresponds with our proposed model in a genetic algorithm, the best result within six heuristic algorithms is obtained as the following Table 3. There are two rules for six heuristics: we selected the shortest traveling time rule and highest utility rule. Each rule considers that there are

Table 3. Comparisons between GA and heuristics

Method	Total staying time	Total traveling time	Total sightseeing time	Total utility
heuristic	390	210	600	35.366
GA	447	153	600	39.8
Gap	+57	−57	0	+4.434

different staying time and three different level of satisfaction. Six heuristics are performed and their results are compared with the proposed GA. Table 3 shows a comparison between GA and the best of heuristics.

Therefore, according to comparative analyses shown in Table 3, it is observed that the total staying time of the tourist route obtained with the genetic algorithm (GA) is longer, the total travelling time shorter, and the final total utility score also higher.

5. **Conclusions.** This study focuses on the recommendation of a higher degree of attraction choice and how much time to stay at the tourist attractions to maximize the satisfactions of tourists. Genetic algorithm-based approach is proposed and compared with six heuristics. The applicability and performance of the suggested approach are demonstrated through a numerical example. From the experimental results it can be applied in a real-world problem for achieving a satisfactory tourism experience. As a future research stochastic travel time and a change in satisfaction incurred from waiting time are also considered for reflecting a real tour situation.

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REFERENCES

[1] World Tourism Organization, *Annual Report 2017*, UNWTO, Madrid, 2018.
[2] R. A. Abbaspour and F. Samadzadegan, Time-dependent personal tour planning and scheduling in metropolises, *Expert Systems with Applications*, vol.38, no.10, pp.12439-12452, 2011.
[3] C. B. Zhu, J. Q. Hu, F. C. Wang, Y. F. Xu and R. Z. Cao, On the tour planning problem, *Annals of Operations Research*, vol.192, no.1, pp.67-86, 2012.
[4] T. Hasuike, H. Katagiri, H. Tsubaki and H. Tsuda, Tour planning for sightseeing with time-dependent satisfactions of activities and traveling times, *American Journal of Operations Research*, vol.3, pp.369-379, 2013.
[5] T. Hasuike, H. Katagiri, H. Tsubaki and H. Tsuda, A flexible tour route planning problem with time-dependent parameters considering rescheduling based on current conditions, *2013 IEEE International Conference on Systems, Man, and Cybernetics*, pp.2091-2096, 2013.
[6] T. Hasuike, H. Katagiri and H. Tsuda, Objective measurement for satisfaction values to sightseeing spots and route recommendation system, *2016 IEEE International Conference on Systems, Man, and Cybernetics*, pp.2699-2704, 2016.
[7] M. A. Awal, J. Rabbi, S. I. Hossain and M. M. A. Hashem, A hybrid approach to plan itinerary for tourists, *2016 IEEE the 5th International Conference on Informatics, Electronics and Vision (ICIEV)*, Dhaka, Bangladesh, 2016.
[8] J. K. Shrestha, Development of a decision support model for optimization of tour time to visit tourist destination points in a city, *The Geographical Journal of Nepal*, vol.10, pp.29-38, 2017.