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Genetic Algorithm based Travelling Route Optimisation for Tourist in Malacca

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Abstract

Malacca state in Malaysia is renowned for its rich cultural and historical significance that tourists love. The need for itinerary planning poses a significant challenge to travellers, potentially leading to inefficiencies and time wastage. The travelling salesman problem (TSP) is an NP-hard problem that can be used to find the optimal solution. The research aims to develop a comprehensive tourist network encompassing all 17 tourist attractions places in Malacca. The genetic algorithm (GA) method uses MATLAB to calculate the shortest route and minimise travel time. A suggested route is formed to assist tourists in making their travel decisions. This contributes to the efficient planning of tourist itineraries to ensure a seamless and enjoyable exploration of the diverse attractions in Malacca. The data was collected through different sources, and the results show that the optimal route for the tourist attractions is 102.411km. The proposed travel route optimisation approach not only caters to the preferences and interests of tourists but also aligns to minimise overall travel time and distance, thereby enhancing the overall tourist experience by providing a simple and easily understandable tourist network.

1. Introduction

Malaysia holds a significant position as a tourist destination, contributing significantly to the country's gross domestic product (GDP). The tourism industry ranks as the third-largest contributor to Malaysia's GDP [1]. Furthermore, Malaysia stands out as the second most-visited country in Southeast Asia, with a substantial revenue contribution of RM 82.2 billion [2]. As a report shows on the Tourism Malaysia Corporate Site, there are 134,728 tourist arrivals and a total of RM 238.73 million in receipts in the year 2021.

Malacca, also known as Melaka in the Malay Language, is a state which is a cultural and historical state located in the southern region of Malaysia. Its capital is Malacca City, and it is a UNESCO World Heritage Site. Malacca holds immense potential for the development of the tourism industry. The total number of tourist arrivals is affected by the COVID-19 pandemic and the implementation of the Movement Control Order (MCO) by the Malaysian government. Although there was a drastic decline in the total number of tourist arrivals, the Department of Statistics Malaysia reports that there were still 3.88 million registered visitors in the year 2021 [3]. This shows that Malacca is still performing well as a tourist destination.

1.1 Motivation of the Study

It's important to think about the route ahead of time when planning a trip. Tourists yearn to visit as many attractions as possible within a limited amount of time. Travellers who don't plan their itinerary might waste time and miss out on important sightseeing opportunities. This is because there are different routes to reach the same destinations, and some are more efficient than others. Choosing a longer route may miss out on some tourist attractions due to limited time. This can lead to disappointment and decrease overall satisfaction with the trip. Therefore, the development of an optimal travel route design plays a crucial role in the overall journey [4].

Travellers should plan their itinerary carefully by considering the distance, travel time, and the availability of attractions along the way. Tourist can optimise their travel experiences and satisfaction by selecting the most efficient routes and allocating enough time for each destination. Proper itinerary planning ensures travellers make the most of their limited time to visit desired attractions and create memorable experiences. It also reduces the chances of encountering unforeseen difficulties and enhances the overall enjoyment of the journey.

The travelling salesman problem (TSP) is a method to optimise travel routes but there are also other ways to solve this problem. Different methods may obtain different solutions. Therefore, in this research we are exploring that:

- To provide a simple and easily understandable tourist network that covers all the attractive locations when tourists visit Malacca.
- To apply the genetic algorithm method in calculating the shortest route and the minimum travelling time.
- To suggest a comprehensive travelling route for tourists making travel decisions so that the travelling time is minimum.

This study presents an easy-to-understand tourist network that helps travellers explore Malacca's attractions using the shortest routes and minimal time. This network acts as a guide for tourists to ensure that they navigate through the city effortlessly and make the most of their trip. Tourists can optimize their travel experience which enables them to have a more enjoyable and enriching visit to Malacca by following the recommended route.

2. Methodology

2.1 Data Collection

The determination of the most popular tourist attractions in Malacca is significant for the study. According to a report reported by the Department of Statistics Malaysia, there were 2.9 million excursionists and 1 million tourists visiting Malacca in 2021 [3]. They show that shopping makes the highest contribution, which is 42% of the total receipts. Since the travellers are mostly from Selangor, Malacca, Negeri Sembilan, Wilayah Persekutuan Kuala Lumpur, and Johor, which are nearby Malacca or from Malacca, the main transportation mode for travellers is land transport. According to the report, land transport represents 99.2% of transportation modes, while private vehicles account for 95.9% of land transport. From the survey, the top 5 destinations which are visited by domestic visitors and tourists in the year 2021 are shown in Table 1.

Table 1 Malacca's top 5 most visited tourist destinations in 2021.

No	Domestics Visitors	Tourists
1	Pantai Klebang	Dataran Pahlawan Melaka Megamall
2	Mahkota Parade	Menara Taming Sari
3	Dataran Pahlawan Melaka Megamall	Porta De Santiago (A' Famosa)
4	Taman Botanikal	Pantai Klebang
5	Pantai Pengkalan Balak	Pantai Puteri

Besides the destinations listed in the table, other places for example, Baba & Nyonya Heritage Museum, Melaka River Cruise, Zoo Melaka and more can also be known as tourist attractions places. The process of collecting data from the report of the Department of Statistics Malaysia, as well as various online and offline publications is carried out to compile a list of attractions.

2.2 Location on Maps

The location of each attraction is identified. Each of the attractions is searched by name and marked in My Maps. Google Maps is a digital map developed by Google Company that helps users find any location they need all over the world. Google My Maps is a feature of Google Maps that allows users to personalize their maps. It has features in both individual and collaboration modes. Besides that, the customised maps can be saved conveniently in Google Drive. Google My Maps helps to create travel routes between different locations. The map can display

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locations and the paths between them. It also shows the precise distances between each location by providing an easy-to-use platform for all mapping needs.

Each location is then connected to create a path and be represented graphically. The locations act as vertices while the paths connecting act as edges. This results in a simple graph diagram with vertices labelled numerically from 1 to 17 according to the corresponding tourist attraction place.

2.3 Research Factors

There are some factors that may affect the travelling time and distance in a trip such as traffic jams, accidents, the number of traffic lights on the road and more. Hence, some assumptions of this study are stated below:

- There are no traffic jams during travelling.
- There is no waiting time at the traffic light.
- There are no accidents during travelling.
- The route is considered as a one-way route.

2.4 Travelling Salesman Problem

The main purpose of this study is to optimise the travelling route among tourist attraction places in Malacca. Travelling Salesman Problem (TSP) is recognised to optimise the route distances among multiple places. The TSP involves finding an optimal route that visits every point exactly once, starting and ending at the same point [5]. It describes a route problem faced by a salesman to determine the shortest route by beginning and returning to the same place while passing every node once [6]. Its purpose is to minimise the total travelling distance [7]. TSP cannot be solved in polynomial time since it is also known as non-deterministic polynomial-time hardness, NP-hard problem [5]. There are some exact and heuristic methods that approach the TSP [8]. It also can be formulated and represented as an undirected weighted graph in Graph Theory [9]. Vertices in the graph correspond to each city while the edges connecting among vertices correspond to the distance among cities [7].

TSP approaches have been introduced to the public but only one approach will be discussed in this project, which is a genetic algorithm (GA). The GA is used to find the shortest route and minimum time for tourist attractions in Malacca to result in a comprehensive network.

The GA is the simulation of chromosome cross-over behaviour that can be transferred into an intelligent optimisation model and search [7]. Individuals that are stronger and healthier have a higher probability of survive in nature. The chromosomes cross-over process exchanges the genetic materials and enable the offspring to inherit a better gene. It is a random method that depends on the natural evolution process [10]. There are many researchers proposed some modified GA models that improve in performance to obtain better solutions, for example, Cellular Genetic Algorithm with Simulated Annealing (SCGA) and Genetic Algorithm with Variable Neighbourhood Search (VNSGA) [11].

The GA introducing an initial chromosome population is the first step in genetic algorithms. It creates individuals by generating an array of genes randomly. The generated genes, which are also called chromosomes, act as the solution to the problem. The offspring production will be carried out next by the process of crossover and mutation after the initial population is formed. A chromosome with a greater fitness value will be chosen as a better solution since each of the chromosomes has its fitness value. The selection of chromosomes is the final step in genetic algorithms. The best chromosome is selected from the population and is used in the next generation. The process will terminate when it meets the termination criteria. The details of the steps mentioned will be elaborated in the following subtopics.

2.4.1 Population Initialisation

The tourist attraction places are numbered from number 1 to 17 and placed together as a population. A chromosome population is established by the permutation of 17 places.

$$P = 17! \tag{1}$$

where P represents the population.

The numbered places are then inserted into a newly created list.

$$A = \{1, 2, 3, \ldots, 17\} \tag{2}$$

where A represents the list of places.

The chromosomes are formed arbitrarily by combining the tourist attraction places as a gene. Every chromosome formed by different sequences of genes is known as an individual, and all the chromosomes are initiated from the population. This population is the starting point for a genetic algorithm to find an optimal or near-optimal solution to the travelling salesman problem.

2.4.2 Fitness Value Evaluation

Fitness value, FV is a value that can be used to determine the best chromosome among the offspring. The fitness value usually refers to the distances among the places discovered in terms of the travelling salesman problem. It is used to evaluate the quality of a potential individual. In nature, organisms with favourable traits, which refer to high fitness value are more likely to survive and reproduce, also passing their traits to the next generation. As a result, a higher fitness value has a greater chance of being selected since they are considered more promising or suitable solutions. The total fitness value for the population is calculated by the formula as shown below.

$$FV = \sum_{i=1}^{n} B(i) \tag{3}$$

where *i* is the individual, *n* is population size, and *B* is the fitness value (distance) of an individual in the population.

2.4.3 Parents Chromosome Selection

After the fitness value is set, the selection of chromosomes can be started. The selection of chromosomes depends on the fitness value and selection probability. The selection probability is used to determine which individuals are chosen to form the next generation. It can balance exploration and exploitation. Exploration involves selecting solutions with lower fitness to explore a wide range of the solution space, while exploitation involves selecting the best solutions to refine the population. The balance is determined by the selection probabilities, which can be adjusted to control the algorithm's behaviour. Every chromosome in the population has the chance to be selected as the selection process is arbitrary. The selection probability for each individual is calculated by using the equation below.

$$P(i) = \frac{B(i)}{FV},\ i = 1, 2, 3, \ldots, n \tag{4}$$

where *P(i)* is the selection probability, *B* is the fitness value (distance) of an individual in the population and *FV* is the fitness value.

2.4.4 Chromosomes Crossover

When two chromosomes are selected from the population, a process called cross-over occurs. This part simulated the process of combining genetic material from two parents' chromosomes to create new chromosomes. A random point is determined within the length of the chromosome as a crossover point. Then, the genetic material is used before the crossover point to simulate a cut at the crossover point. After that, it retrieves the dimensions of the remaining genetic material in the parent chromosome and combines the cut genetic material with the remaining genetic material to create a new chromosome. The two chromosomes will exchange their genes, which may improve fitness value by mixing and matching traits from good parent solutions. A new generation of chromosomes is formed.

2.4.5 Chromosome Mutation

Besides the inherited gene from their parents, the new generation of offspring formed has an evolution in their genes. An interchange of two genes also known as mutation occurs arbitrarily in a chromosome. This simulates the mutation process in a genetic algorithm that results in the swapped value. The genes will be swapped at the mutation point in the parent chromosome. The mutation point for the two chromosomes must be different. This introduces genetic diversity to explore the different genetic configurations in the population.

2.4.6 Termination Criteria

The process repeats until it is achieved by 1000 total generations. The optimum solution is obtained from the model.

3. Results and Discussion

There are 17 selected tourist attractions in Malacca. The list of the selected places, their number representation, latitude, and longitude are shown in Table 2.

Table 2 Numbering of Tourist Attractions.

Number Representation	Tourist Attraction Places	Latitude	Longitude
1	A Famosa	2.19179	102.25036
2	Baba & Nyonya Heritage Museum	2.19533	102.24671
3	Cheng Hoon Teng Temple	2.19749	102.24683
4	Dataran Pahlawan Melaka Megamall	2.18975	102.25261
5	Dutch Square (Red Square)	2.19433	102.24912
6	Klebang Beach	2.21638	102.19250
7	Mahkota Parade	2.18837	102.25014
8	Melaka Butterfly & Reptile Sanctuary	2.29966	102.31128
9	Melaka Sultanate Palace Musuem	2.19257	102.25057
10	Melaka Straits Mosque	2.17900	102.24897
11	Melaka River Cruise	2.20734	102.25181
12	Muzium Samudera (Flor de La Mar)	2.19189	102.24661
13	Pantai Pengkalan Balak Melaka	2.32222	102.07003
14	Portuguese Settlement, Melaka	2.18475	102.26757
15	Puteri Bay Melaka	2.22942	102.14876
16	The Shore Sky Tower	2.20264	102.24963
17	Zoo Melaka	2.27655	102.29865

The latitude and longitude of each location are used to plot the node of the simple graph diagram that represents the travelling route. The figures below show the node which represents the location of each tourist attraction places in Malacca that is generated by MATLAB.

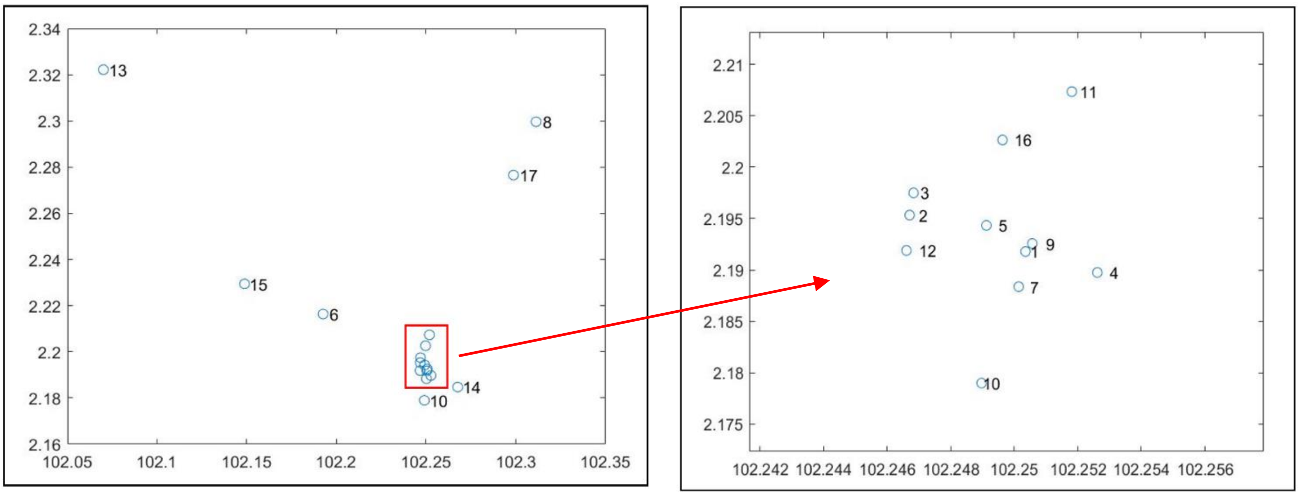

Fig. 1 Simple graph diagram representing the location of each tourist attraction places in Malacca by MATLAB.

The distance between each tourist attraction is written in a matrix. The distance matrix and the number representation of every location are used in the GA model which is coded and computed using MATLAB. The distance matrix between every location is shown in Table 3.

Table 3 Distances between tourist attraction places (in km) for location 1 to location 9.

Location	Distances (km)								
From \ To	1	2	3	4	5	6	7	8	9
1		1.800	3.100	0.450	1.500	9.600	0.800	17.000	0.001
2	2.900		1.800	3.100	2.000	8.100	3.300	15.800	3.700
3	2.300	1.700		2.500	1.400	9.200	2.800	15.400	5.400
4	0.550	1.800	3.100		1.500	9.400	0.550	17.200	0.550
5	1.000	0.400	2.200	1.500		8.500	1.500	15.400	1.700
6	9.200	7.900	8.700	9.500	9.000		8.300	20.400	9.200
7	0.800	2.100	3.300	0.260	1.700	9.300		17.500	0.800
8	16.100	15.500	15.900	16.300	15.200	22.100	16.700		16.800
9	0.011	1.800	5.700	2.600	1.500	10.000	3.500	17.200	
10	3.100	4.400	6.200	4.000	4.100	11.400	2.800	18.500	3.200
11	2.700	2.200	2.500	3.000	1.800	9.400	3.300	13.700	3.500
12	0.500	2.500	3.800	0.700	2.200	9.800	1.100	17.900	1.300
13	34.500	33.300	33.900	34.800	34.200	25.700	33.600	33.600	34.500
14	2.800	3.700	4.500	4.100	3.300	11.800	3.000	16.100	2.800
15	14.200	13.000	13.900	14.500	14.100	5.900	13.800	25.600	14.800
16	2.700	2.200	2.500	3.000	1.900	9.400	3.300	14.800	3.500
17	13.300	12.700	13.000	13.500	12.400	18.500	13.900	5.200	15.400

Table 4 Distances between tourist attraction places (in km) for location 10 to location 17.

Location	Distances (km)							
From \ To	10	11	12	13	14	15	16	17
1	3.400	3.000	1.900	33.700	3.000	13.900	2.200	14.200
2	5.800	2.400	2.400	32.300	4.900	12.500	2.300	13.400
3	6.200	2.000	1.800	32.700	4.200	13.600	1.900	13.000
4	2.900	3.000	1.900	33.400	3.000	13.700	2.200	14.200
5	4.100	2.200	0.450	33.000	3.700	13.300	1.300	12.900
6	10.800	9.200	9.400	26.100	11.500	5.900	9.100	17.900
7	3.200	4.000	2.100	33.500	3.300	13.700	2.500	14.800
8	19.400	13.800	15.600	34.100	16.500	26.500	14.700	3.100
9	4.700	3.800	1.900	34.500	3.000	14.700	2.200	14.200
10		6.400	4.500	36.100	4.800	16.300	5.300	16.000
11	5.900		2.300	33.300	4.000	14.200	1.300	11.200
12	3.700	4.200		34.400	3.700	14.700	2.900	15.500
13	36.200	32.700	34.300		36.800	21.500	34.500	35.900
14	4.000	4.300	3.700	36.300		16.600	3.600	13.600
15	16.400	13.900	14.500	22.700	17.000		13.800	24.500
16	5.900	1.600	2.300	32.900	4.000	14.200		12.400
17	16.600	11.000	12.700	33.400	13.700	22.800	11.900	

The optimal solution for the Malacca tourist attractions is obtained by using MATLAB after 1000 iterations. The computation time for the GA model to run 1000 iterations by using MATLAB is 33 minutes 17 seconds. The optimal solution obtained has a minimum total distance of 102.411km. The optimal route generated by MATLAB is 3-5-12-1-9-14-10-7-4-2-6-15-13-8-17-11-16. The route starts at Cheng Hoon Teng Temple (Location 3) and is then followed by Dutch Square (Location 5). The route continues with Muzium Samudera (Location 12), A Famosa (Location 1), Melaka Sultanate Palace (Location 9), Portuguese Settlement, Melaka (Location 14), Melaka Straits Mosque (Location 10), Mahkota Parade (Location 7), Dataran Pahlawan Melaka Megamall (Location 4), Baba & Nyonya Heritage Museum (Location 2), Klebang Beach (Location 6), Puteri Bay Melaka (Location 15), Pantai Pengkalan Balak Melaka (Location 13), Melaka Butterfly & Reptile Sanctuary (Location 8), Zoo Melaka (Location 17), Melaka River Cruise (Location 11) and lastly ends at The Shore Sky Tower (Location 16).

The figures below show the optimal route from the genetic algorithm generated by MATLAB.

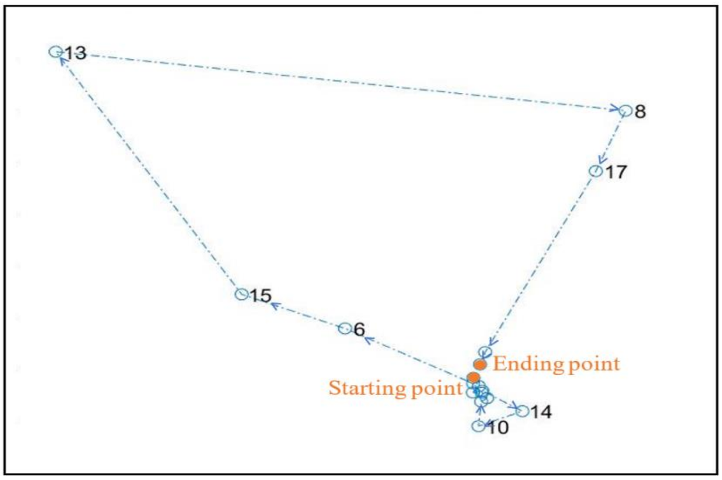

Fig. 2 Optimal route from the genetic algorithm generated by MATLAB.

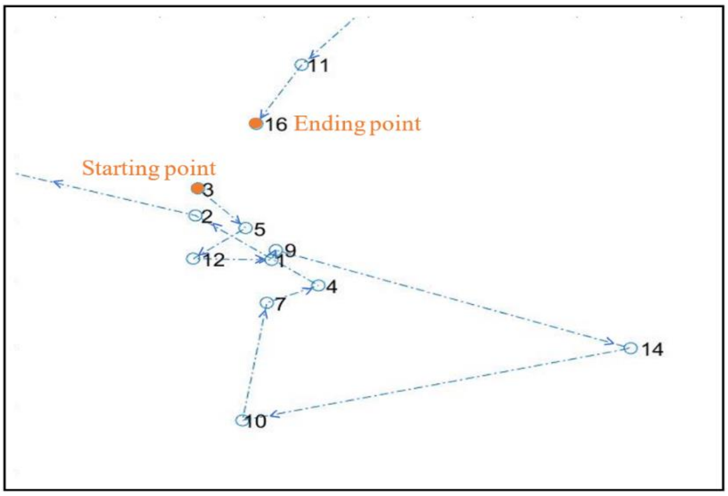

Fig. 3 Zoomed-in view of the overlap nodes for the optimal route from the genetic algorithm generated by MATLAB.

From the figures above, there are lines which also known as edge that connect every node and form a simple and clear network. The nodes represent the location of each attraction places, and the edges represent the path that connect the attraction places. The graph diagram is then transferred to the map as an overview.

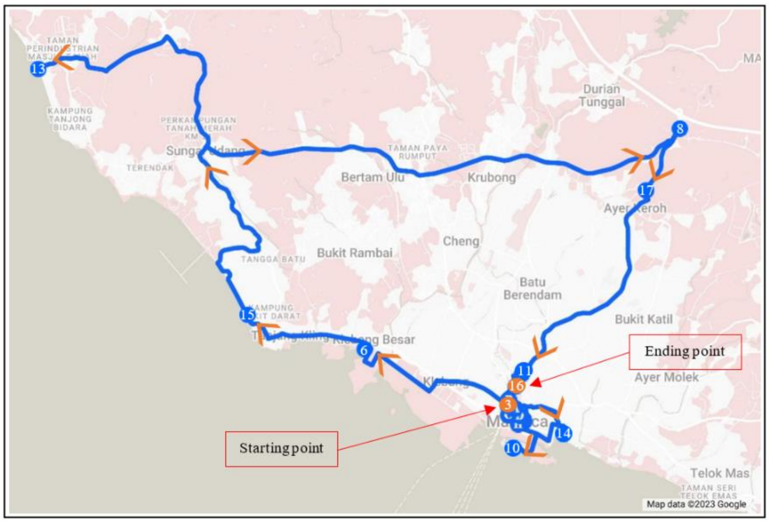

Fig. 4 Optimal route from the genetic algorithm in the map.

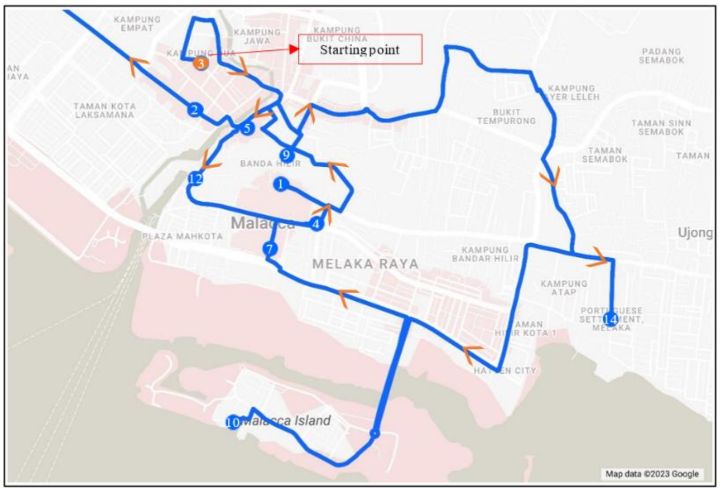

Fig. 5 Zoomed-in view of the overlap locations for the optimal route from the genetic algorithm in the map.

The map diagrams give a reality insight of the optimal route obtained by MATLAB. A summary of the optimal solution is shown in the figure below to give a simple overview of the Malacca travelling route for tourist attractions places to assist tourist's understandings.

Fig. 6 Simple overview of Malacca travelling route for tourist attractions places.

4. Conclusion

A simple and clear network that offers tourists a valuable tool for exploring Malacca city is obtained. Travellers can minimise their time at each attraction and ensure a more immersive experience by following the suggested route with a total travel distance of 102.411km.

The application of the genetic algorithm has made travel planning more efficient. MATLAB uses about 33 minutes 17 seconds to calculate and compute the optimal route for 1000 iterations from the genetic algorithms model.

The implementation of the tourist network has opened new possibilities for streamlining travel planning processes. The parameter that is considered in this study is only distance. Therefore, there are some other parameters such as time constraints, two-way routes and more that can be considered in the future study to obtain a more optimal solution for the travelling route planning and optimisation.

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Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: ***study conception and design:*** *Mahathir Mohamad, Kek Sie Long, Tan Q-Yee;* ***data collection:*** *Tan Q-Yee;* ***analysis and interpretation of results:*** *Mahathir Mohamad, Kek Sie Long, Tan Q-Yee;* ***draft manuscript preparation:*** *Tan Q-Yee. All authors reviewed the results and approved the final version of the manuscript.*

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