Development of intelligent virtual assistant for planning the optimal travel route

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Abstract. In this article the developing of an intelligent travel planning system is considered. Travel planning system includes an intelligent search module, an optimal budget planning module and a module for building an optimal route. The intelligent search module acts as a recommendation system and offers the user sights and interesting places to visit. The optimal budget allocation module helps the user to plan their finances taking into account their preferences for the comfort of travel and accommodation. Based on the obtained data, the optimal route planning module plans a schedule of visits to the selected attractions. In this article, we consider the production model of knowledge representation to determine the most preferred travel destinations for tourists, the application of a genetic algorithm for the optimal distribution of the travel budget and the modification of the method of imitation of an ant colony to find the optimal route between the cities.

1. Introduction

In the age of rapidly developing technologies, the service sector provides its potential customers with more information through the Internet. This phenomenon has not spared the sphere of tourist services. In the world network now we can find offers from travel companies and Internet services, as well as all kinds of travel reviews and recommendations. The possibility to order the service from the comfort of home, due to the fact that now more and more people prefer to plan their own travel, which makes it possible to get the most out of the trip, save the budget, as well as the right of tourists to choose the duration of travel in general and in particular localities.

Thus, according to a study conducted by the Analytical center NAFI, in 2018-2019, more Russians began to travel both inside the country and abroad. The growth was primarily due to those who prefer to plan their own vacation, while the number of clients of travel agencies has not changed. Since 2018, the share of Russians who prefer to organize their own vacation has increased-book tickets (from 28% to 34%) and rent housing (from 26% to 32%). Young and middle-aged people (up to 44 years) often prefer to organize their holidays themselves: buy tickets (46%) and book accommodation (45%). Among people over 60, only one in ten do so (15% buy tickets, 12% book accommodation).

However, independent travel planning is associated with a number of difficulties: starting with the choice of online travel planning resources, and ending with the optimal distribution of travel time. In these circumstances, it becomes relevant to develop an intelligent virtual assistant, which helps on the
basis of a small survey of the user to provide him with information about the most suitable travel destinations, as well as to make the optimal route from the point of view of the duration of their visit.

2. Related works

Currently, various systems are being actively developed to provide travel advice to travelers. This direction of scientific research is relevant, because today there is no universal algorithm for solving this problem. Consider some examples of approaches proposed by various authors.

The authors of the article [1] the TourWithMe app for Android was developed. A distinctive feature of this work is that the proposed approach is focused not on one tourist, but on a group of tourists-groups can be formed independently, or with the help of an application that automatically selects the appropriate company for the user. Recommendations are created based on the current geolocation of the tourist provided by mobile devices. The approach proposed by the authors implicitly takes into account the interest of the user based on the places he visits, the amount of time spent in each place, and the time spent on trips to these places, and also finds other tourists in the immediate vicinity of the user and suggests forming a group with those users who have similar interests. Once the appropriate group of tourists is selected, the application selects interesting places to visit.

The authors of the work [2] an approach is also proposed that recommends an individual travel route taking into account the interests of the user. This approach is implemented as a web application CT-Planner4 using an evolutionary algorithm.

In [3] the algorithm of PersTour formation of the recommendation of the personal tourist route is offered. The algorithm takes into account the popularity of various tourist places and attractions, as well as the user's preferences, which are automatically derived from the actual sequences of his travels based on photos with geotags. The approach proposed by the authors calculates the duration of each visit, taking into account the timestamps of the first and last photos taken in the visited place. The approach uses this information to assess the user's interest in different categories of tourist places.

In the works of [4, 5, 6] the authors propose approaches that determine the interests of the user for different categories of tourist places in accordance with the number of visited places belonging to a particular category. To solve this problem, geotagged photos from the user's social networks are used to restore the history of the places they visited. Based on information about the user’s interests, the approaches under consideration provide recommendations in the form of a ranked list of potential tourist places and attractions that the user can visit.

The approach to the development of individual tourist recommendations presented in the article [7], uses data on crowdsourcing marks of users in the service Jie Pang (China), on the basis of which the most preferred places for the user to visit are determined. Recommendations are generated by the combined consideration of user preferences and space-time constraints using heuristic algorithms. Since the user's interests can vary depending on the time of day, this approach also divides the day into six time slots and calculates the user's interests for each time slot separately.

The paper [8] an approach to solving the problem of recommendations of tourist destinations using cluster analysis (Data Mining) is proposed. The authors of the article developed a recommendation system City Rec, which allows choosing the city for travel. The proposed approach is based on the use of data characterizing the city—the climate and the cost of a trip to a given city.

In the study [9] the authors develop an algorithm for hotel recommendations based on machine learning, which provides the user with a list of the most optimal hotels based on their booking history, as well as information about booking flights.

A review of studies has shown that most of the existing solutions allow either only optimizing the time characteristics of travel, or only choosing the place of travel that most satisfies the wishes of the user. This study is aimed at developing a software-algorithmic solution to the problem of automatic formation of the travel route on the basis of a combined method that combines a production model of knowledge representation to determine the most preferred travel destinations for tourists, the use of a
genetic algorithm for optimal distribution of the travel budget and modification of the method of imitation of an ant colony to find the optimal route between cities.

3. Theoretical aspects of a research
To form a transport and logistics structure within the project, the following tasks are solved:

- Identify possible tourist destinations based on user preferences.
- Optimization of funds allocated for travel.
- Time resource planning.

Let us consider them in more detail.

3.1. Intelligent Module for Taking into Account the Wishes
The main component of the system is the intelligent module (Figure 1).

![Figure 1. Virtual Assistant Intelligent Module Architecture.](image)

Many regions of Russia have a rich tourist potential, represented by many natural, cultural and spiritual treasures, developed infrastructure, many tourist routes. A rich selection of diverse destinations allows tourists enjoying their holidays according to their taste and preferences, whether it is the scenery of wildlife or large Metropolitan areas with their attractions.

Thus, tourism in the Russian Federation can be divided into the following categories: beach holidays, skiing and snowboarding, extreme sports, shopping, treatment / sanatoriums, history and culture, cruise holidays, nature.

The choice of climate, the most comfortable for the user, will also help to narrow the area of suitable places for travel. All climatic zones in Russia can be divided into 3 groups: subtropical/tropical climate, temperate climate, subarctic climate.

The mode of transport by which we can get from one point to another: car, bus, train / train.

Let there be a set of data (the fragment is presented in table 1) containing a list of subjects of the Russian Federation, as well as the types of recreation available in them and climate information characterizing each subject.

In the Table 1, the figures indicate the presence of a particular feature in a particular region of the Russian Federation, where " -1 " - is absent, "1" - is present.

The intelligent module of the virtual assistant consistently asks questions to the user and, receiving answers to them, filters the initial list of regions of the Russian Federation, thereby leaving the most
suitable places for the user's requests to visit. For each question, the user can give a specific answer or specify that this criterion can be ignored when creating a recommendation.

### Table 1. Information about the subjects of the Russian Federation

| №  | ID  | Name of region | Beach | Skiing & snowboarding | Extreme sport | Shopping | Treatment/motels | History and culture | Cruise | Nature | Tropical/subtropical | Temperate | Subarctic | Up to 1500₽ | From 1500₽ to 3000₽ | More than 3000₽ | Car | Bus | Train |
|----|-----|----------------|-------|-----------------------|---------------|---------|-----------------|---------------------|--------|--------|---------------------|-----------|-----------|-------------|----------------------|------------------|-----|-----|------|
| 1  | 22  | Altai Krai     | -1    | 1                     | 1             | 1       | -1              | 1                   | -1     | 1       | 1                   | 1         | 1         | 1           | 1                     | 1                |     |     |      |
| 2  | 28  | Amur Oblast    | -1    | 1                     | 1             | 1       | 1               | -1                  | -1     | 1       | 1                   | 1         | 1         | 1           | 1                     | 1                |     |     |      |
| 3  | 29  | Arkhangels Oblast | 1     | 1                     | 1             | 1       | 1               | -1                  | -1     | 1       | 1                   | 1         | 1         | 1           | 1                     | 1                |     |     |      |
| ...|     |                |       |                       |               |         |                 |                      |        |         |                     |           |           |             |                       |                  |     |     |      |
| 83 | 89  | YaNAO          | -1    | 1                     | 1             | 1       | 1               | -1                  | -1     | 1       | 1                   | 1         | 1         | 1           | 1                     | 1                |     |     |      |
| 84 | 76  | Yaroslavl Oblast | -1    | 1                     | 1             | 1       | 1               | -1                  | -1     | 1       | 1                   | 1         | 1         | 1           | 1                     | 1                |     |     |      |

3.2. Optimization of Expenses of Funds Taking into Account Preferences of the User

After the system will select the direction of travel, taking into account the interests of the user regarding the pastime on vacation, the module of optimal budget allocation will help him to plan finances correctly.

At this step, the system will ask the user to enter data on the total allocated budget, which consists of funds for travel between cities and accommodation, as well as specify priorities for these two components (comfort of living and comfort of travel).

To solve the problem of cost optimization of funds with the user preferences on a tight budget apply optimization methods of functions of several variables, which are easy to take into account the constraints on the variables and on the permissible scope of the search.

We will solve the problem of the form (1)-(3), in which: \( n \) is the number of cities; \( t_i \) is the number of days of staying in the \( i \)-th city; \( \Delta t_i \) is travel time between cities; \( C \) is the total budget; \( c_{ij} \) is the price of the hotel \( i \)-th city \( j \)-th level; \( L_t \) is a comfort of hotel; \( k_1 \) is a priority of comfort of accommodation; \( k_2 \) is a priority of comfort of trip; \( k_3 \) is a priority of expenses on sights; \( T \) is a total number of days of rest; \( L_p \) is a comfort in movement; \( p_{ri} \) is a fare between cities.

The mathematical formulation of the problem has the form:

\[
k_1 \left( \sum_{i=1}^{n} k_i \right)^{-1} \cdot \sum_{i,j=1}^{n} L_{ij} t_i + k_2 \left( \sum_{i=1}^{n} k_i \right)^{-1} \cdot \sum_{i,j=1}^{n} L_{ij} \Delta t_i - k_3 \left( \sum_{i=1}^{n} k_i \right)^{-1} \cdot \sum_{i,j=1}^{n} c_{ij} t_i \rightarrow \max,
\]

\[
T \leq \sum_{i=1}^{n} t_i + \sum_{i,j=1}^{n} L_{ij},
\]
\[ C \leq \sum_{i,j=1}^{n} c_{ij} f_i + \sum_{i=1}^{n} p r_i, \]  

(3)

The result of this stage is a list of cities suitable for the interests and budget of the user. Before proceeding to the final stage, the user is asked to choose from the list of cities that he would like to visit.

3.3. Construction of the Optimal Route

At this stage, the intelligent assistant makes a trip plan in the form of a tourist route. The tourist route includes a full description of all the places planned to visit, drawing them on an interactive map loaded GIS-service. The analysis of heuristic algorithms for solving the traveling Salesman Problem (TSP) showed that ant algorithms achieve greater accuracy in finding the optimal route. Therefore, to solve this problem, we will use a modified algorithm of the method of imitation of an ant colony.

Since the problem we solve takes into account not only the distance between cities, but also the priority of visiting them, then the probability of the \( k \)-th ant moving from city \( i \) to city \( j \) on the \( t \)-th iteration should be affected equally by both these parameters. This result will help to achieve normalization of priorities of visited places:

\[ pr_i = pr_i \left( pr_i \cdot S_{pr} \right)^{-1}, \quad i = 1, n, \]  

(4)

where \( n \) is the number of vertices of the graph, \( pr_i \) is the priority to visit the \( i \)-th vertex, and \( S_{pr} \) is the normalization factor calculated by the formula:

\[ S_{pr} = \sum_{pr_i \neq pr_j} pr_i \left( pr_i \right)^{-1}, \forall h < j, h \in N. \]  

(5)

Let \( M_k(t) \) is the set of numbers of vertices visited by the \( k \)-th ant at the \( t \)-th iteration. We suppose that the route with the biggest value of \( F = \sum_{i \in M_k(t)} pr_i \) is the best route.

In addition, the probability-proportional rule, which determines the probability of the \( k \)-th ant moving from point \( i \) to point \( j \) at the \( t \)-th iteration, plays an important role in the algorithm:

\[
\begin{align*}
P_{i,j,k}(t) &= \left[ \tau_{ij}(t) \right]^\alpha \cdot \left[ \eta_{ij} \right]^\beta \left( \sum_{\ell \in J_{i,k}} \left[ \tau_{\ell,j}(t) \right]^\alpha \cdot \left[ \eta_{\ell,j} \right]^\beta \right)^{-1}, \quad \text{if } j \in J_{i,k}, \\
P_{i,j,k}(t) &= 0, \quad \text{if } j \not\in J_{i,k},
\end{align*}
\]  

(6)

where \( \eta_{ij} = 1 / D_{ij} \) is the attraction of the path from \( i \) to the \( j \) vertex; \( D_{ij} \) is the geometric distance in two-dimensional space between the \( x_i \) and \( x_j \) vertices, defined as

\[ D_{ij} = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2}, \]

where \((x_i, y_i)\) is the coordinates of the city \( i \), and \((x_j, y_j)\) is the coordinates of the city \( j \); \( J_{i,k} \) is a set of unvisited cities for the \( k \) agent located at the top \( x_i \); \( \alpha \) and \( \beta \) are two adjustable parameters that specify the weight of the pheromone trace and visibility when choosing a route. If \( \alpha = 0 \) then the nearest city will be chosen, which corresponds to the greedy algorithm in classical optimization theory. While \( \beta = 0 \) only pheromone amplification works, this leads to the fact that the routes are degenerate to the same suboptimal solution.

The ant colony system dynamically determines the amount of pheromone deposited on the ribs:
\[ \forall D_{ij} \in A \quad \tau_{ij}(t+1) = (1-\rho) \cdot \tau_{ij}(t) + \Delta \tau_{ij}(t), \]

where \( \tau_{ij}(t) \) is the amount of pheromone deposited on the edge \( D_{ij} \) during the time interval \( [t-1,t] \), i.e. the a posteriori probability of using the edge \( D_{ij} \), i.e. the conditional probability of the event provided that the a posteriori data obtained after the experiment are known; \( 0 < \rho < 1 \) is the pheromone evaporation coefficient; \( \Delta \tau_{ij}(t) \) is the variable showing how much the amount of pheromone on the edge \( D_{ij} \) will increase in the time interval \( [t-1,t] \), it is also the path length.

\( \Delta \tau_{ij}(t) \) is the sum of the total pheromone deposited by each agent that has passed over a given edge in a given time period, i.e.,

\[ \Delta \tau_{ij} = \sum_k \Delta \tau_{ij,k}(t). \]  

After each iteration, a pheromone is deposited on the edge \((i, j)\), determined by the formula:

\[ \Delta \tau_{ij,k}(t) = \begin{cases} Q \cdot \left( \frac{1}{\sqrt{\sum_{k \in T_i(t)} \cdot (L_k(t) \cdot F) \cdot f_{i,j}}} \right), & \text{if } (i, j) \in T_i(t) \text{,} \\ 0, & \text{if } (i, j) \notin T_i(t). \end{cases} \]

where \( T_i(t) \) is the route traveled by ant \( k \) on iteration \( t \); \( L_k(t) \) is the length of this route; \( f_{i,j} = \sum_{i \in T_i(t)} pr_i \cdot F = \max_{k \in T_i(t)} f_{i,j} \cdot Q \) is an adjustable parameter whose value is chosen of the same order with the length of the optimal route (\( S_{\text{max}} \) is the maximum duration of the journey).

Since the number of hours to stay in each city is limited, the selection of those paths, the length of which would not exceed this value. If we find a longer path, the search should be completed in advance. At the same time, the time for the return journey is automatically taken into account. In addition, in all vertices it is necessary to make a transition along the loop (time to stop in each city).

4. Experiment

For optimal distribution of funds allocated for the trip, we solve the problem of multidimensional conditional optimization of the form (1)-(3) with the help of a genetic algorithm. Problem (1)-(3) is a linear programming problem (the objective function is linear) with linear constraints of the form of inequalities.

One of the main problems in applying a genetic algorithm is to make sure that the resulting solution is correct, i.e. is the solution of the original problem. To solve this problem, consider some test problem, the solution of which can be found by the simplex method of Danzig, which we take as a reference.

Consider the test problem (10), in which it is necessary to find the maximum value of the linear objective function under the constraints given by the system of linear inequalities

\[
\begin{align*}
3x_1 - 4x_2 & \rightarrow \max, \\
6x_1 + 6x_2 & \leq 36, \\
4x_1 + 8x_2 & \leq 32, \\
x_1, x_2 & \geq 0,
\end{align*}
\]

the solution of which can be found by the simplex method of Danzig and which we take as a reference. The solution of this problem by the simplex method has the form: \( x = (x_1, x_2) = (6, 0) \), \( f_{\text{max}} = 18. \)
Now let us solve the problem (10) using genetic algorithm. The best results obtained for the test problem are given in Table II. It should be noted that when using rank selection, a reliable solution of the problem was obtained. However, when using selection on the principle of roulette, the resulting solution is far from true, most likely, the selected number of generations (500) is insufficient.

Then we vary the probability values of different mutation operators with the best results obtained (for rank selection) from the previous experiment. Three series of experiments were carried out using three mutation operators in different combinations (table 3), two mutation operators in different combinations (table 4) and only one mutation operator (table 5).

Similar experiments were carried out with one, two and three crossing operators with the best combination of mutation operators obtained: uniform – 0.36, boundary-0.36, non-uniform and full non-uniform-0.0. In all cases the same solution coinciding with the true solution of the problem (10) is obtained. Thus, for the considered problem it is possible to be limited to use only one operator of crossing.

### Table 2. Best results obtained.

| True solution of the problem | Selection on the principle of roulette | Rank selection |
|------------------------------|--------------------------------------|----------------|
|                              | The mutation probability is 0.56, crosses 0.80 | The mutation probability is 0.72, crosses 0.48 |
|--------------------------------|--------------------------------------|----------------|
| $f = 18$                      | 17.9557, 0.1565, (17.9351, 17.9763)   | 17.9997, 0.0000, (17.9997, 18.0000) |
| $x_1 = 6$                     | 5.9871, 0.0363, (5.9751, 5.9991)     | 5.9999, 0.0000, (5.9999, 6.0000) |
| $x_2 = 0$                     | 0.0014, 0.0303, (0.0005, 0.0023)     | 0.0000, 0.0000, (0.0000, 0.0000) |
| time, sec                     | 0.3254, 0.0061, (0.3000, 0.0075)     |                |

### Table 3. Using three mutation operators.

| Probability of mutation | Mean   | Std. Dev | 95% Conf. Int. |
|-------------------------|--------|----------|----------------|
| Uniform 0.24, boundary 0.24, uneven 0.24 | 18.0000 | 0.0000 | (18.0000, 18.0000) |
| Uniform 0.24, boundary 0.24, full uneven 0.24 | 18.0000 | 0.0000 | (18.0000, 18.0000) |
| Boundary 0.24, uneven 0.24, full uneven 0.24 | 17.9992 | 0.0018 | (17.9987, 17.9995) |

### Table 4. Using two mutation operators.

| Probability of mutation | Mean   | Std. Dev | 95% Conf. Int. |
|-------------------------|--------|----------|----------------|
| Uniform 0.36, boundary 0.36 | 18.0000 | 0.0000 | (18.0000, 18.0000) |
| Uniform 0.36, uneven 0.36 | 17.7292 | 0.1529 | (17.7079, 17.7505) |
| Uniform 0.36, full uneven 0.36 | 17.8587 | 0.1229 | (17.8416, 17.8759) |
| Boundary 0.36, uneven 0.36 | 17.9955 | 0.0079 | (17.9944, 17.9966) |
| Boundary 0.36, full uneven 0.36 | 17.9998 | 0.0002 | (17.9998, 17.9999) |
| Uneven 0.36, full uneven 0.36 | 17.8448 | 0.2118 | (17.8153, 17.8744) |

### Table 5. Using single mutation operators.

| Probability of mutation | Mean   | Std. Dev | 95% Conf. Int. |
|-------------------------|--------|----------|----------------|
| Uniform 0.36, boundary 0.36 | 18.0000 | 0.0000 | (18.0000, 18.0000) |
| Uniform 0.36, uneven 0.36 | 17.7292 | 0.1529 | (17.7079, 17.7505) |
| Uniform 0.36, full uneven 0.36 | 17.8587 | 0.1229 | (17.8416, 17.8759) |
| Boundary 0.36, uneven 0.36 | 17.9955 | 0.0079 | (17.9944, 17.9966) |
| Boundary 0.36, full uneven 0.36 | 17.9998 | 0.0002 | (17.9998, 17.9999) |
| Uneven 0.36, full uneven 0.36 | 17.8448 | 0.2118 | (17.8153, 17.8744) |
Thus, in the course of the experiments, the following quasi-optimal parameters of the developed genetic algorithm were determined:

- Rank selection.
- Probability of uniform 0.36; boundary - 0.36; uneven and complete uneven mutation - 0.0.
- Any of the four cross operators used with a probability of 0.48.

All other parameters have default values. Moreover, for test problem (10), a solution was obtained that coincided with the true solution of the problem within six decimal places (table 6).

**Table 6. Solution of the problem (10) at quasi-optimal values of algorithm parameters.**

| The true solution of the problem | Mean      | Std. Dev  | 95% Conf. Int.              |
|---------------------------------|-----------|-----------|----------------------------|
| \( f = 18 \)                   | 18.000000 | 0.000000  | (18.000000, 18.000000)     |
| \( x_1 = 6 \)                  | 6.000000  | 0.000000  | (6.000000, 6.000000)       |
| \( x_2 = 0 \)                  | 0.000000  | 0.000000  | (0.000000, 0.000000)       |
| time, sec                       | 0.292955  | 0.005644  |                            |

5. Conclusion

The work is devoted to the development of a software-algorithmic solution to the problem of planning the optimal travel route, consisting of three modules, each of which solves one of the problems. Thus, the intelligent module for selecting places for travel allows defining a number of settlements, as well as attractions and places of rest in them.

Based on the data obtained as a result of the work of the intelligent module, the optimal budget allocation module plans money based on user preferences. This problem is reduced to the problem of multidimensional conditional optimization, for the solution of which an approach based on the use of a genetic algorithm was applied. The choice of this method of solution is due to the following factors:

- The genetic algorithm does not have significant requirements for the types of objective functions and constraints (various objective functions and types of constraints defined on discrete, continuous, and mixed universal sets can be used).
- When using classical step-by-step techniques, a global optimum can be found only when the problem has the property of convexity. At the same time, the evolutionary operations of genetic algorithms make it possible to efficiently find the global optimum.
- The genetic algorithm uses both probabilistic rules for generating new points for analysis, and deterministic rules for moving from one point to another. The simultaneous use of elements of randomness and determinism gives a much greater effect than separate.

The module of the optimal route, based on the application of the modified method of imitation of the ant colony, constructs the most optimal tourist route for the trip between the selected objects. The search for the optimal route by mathematical methods required the development of an appropriate model. In the work, a modification of the classical ant algorithm is proposed, which allows solving the problem with all the restrictions specified by the user. As a result of the work, the virtual assistant enables the user to specify requirements for building the route, and also performs calculations to find the optimal path and graphically presents the results of the study on an interactive map of the loaded GIS service.
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