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STUDY OF THE METHODS OF TOURIST TRAVELS FORMATION

Objective of the paper is the analysis of the methods of decision-making in the sphere of tourist travels planning. Aim of tourist travels is to get bright impressions and the correct choice of the site of the travel, well-planned route will certainly improve the impressions of the tourist trip. Goal of the given study is to improve the efficiency of users support while choosing the direction of the tourist travel and planning the sequence of the sites to visit by means of development the quality software in this field. For the development of the corresponding software it is suggested to use the combined decision-taking methods, which take into account individual features and advantages of the users. Methods, suitable for the solution of the given task were considered, these methods included linear additive convolution with normalizing factors and weight coefficients, combinatorics, travelling salesman problem. The improved algorithm of selection and planning of the tourist trips, which uses the combination of these methods for obtaining the best solution for the user was proposed. Experimental study of the suggested algorithm was carried out, the study enabled to verify its efficiency at all the stages. Experimental study was performed at various types of the input data and took into account different wishes and advantages of the users. For the formation of the datasets of the experiments different sources of data about cities, countries and tourist attractions were analyzed and compared. Algorithm was realized and integrated in the mobile application for Android with the possibility of expansion, the methodology of pure architecture was applied. The suggested solution can be integrated in other system of tourist sphere. By the results of the research the following conclusion can be made: the suggested improved algorithm and software solution, developed on its base, allows to take into consideration the advantages of the users and improve the experience of tourist travels planning.

Key words: *multicriterial optimization, linear additive convolution, combinations, travelling salesman problem, travels planning.*

Introduction

Nowadays, due to easy access to the developed transport networks, tourists do not practically have any technical limitations regarding the possibility of travelling. Several decades ago it was not so easy to travel as a results of high prices. limited possibilities of obtaining visa and inaccessibility of transport facilities.

Main problem of the travellers today is wheather to travel or not but where to travel and how. Numerous services tried to answer this question, such as «Trip Adviser», sites of tourist agences and even Google services. However, as it will be shown further, all these systems can not ideally solve this problem.

As a rule, tourist decides where to go proceeding from the previours own or recommended experience (or lack of the experience), preferences, cultural interists, personal features, type of trips and certainly, prices. Above-mentioned services, do not take into account the wishes of many users and do not propose the best variants. Besides, there is a large segment of travellers who prefer to move constantly in the country/city, interesting for them, looking for new impresions. Such low level activities and wishes are seldom covered by the available services and the user has to be responsible himself for his wishes. Planning of such logistic of the trip can be very complicated for the greater part of people.

Objective of the paper is to concentrate on the analysis and development of the automatic methods of planning and optimization of the trip preparation and improvement of the user`s experience.

There exist numerous travelling sites. When the user wants to plan the vocations first what the majority of sites ask is the destination. For instance, service «RomeToRio» – helps to plan routes, in «Inspirock» – user may set the points of destination and the service proposes the complete list of the available activities in the cities, regions. And if the user does not have the desired directions there are three variants.

The first variant – address for help to expert-human. There are planning sites where it is necessary to input the desired destination point, idea, budget, needs and other advantages then the user is connected with the expert for trip planning. In such a way tourist companies operate.

The second variant – usage of the routes with several filters. There are sites with certain general filters and searching facilities. Thus, these general filters provide general results which are not concentrated on the specific user. Or vice versa, certain places will be omitted, as they belong to other wide category but in reality they may be good variant by other criteria.

The examples include "Great Escape", it is an aggregate of the flights shedule and searching system with certain filters. Another example is called «Google Trips», where key functions are the maps, possibility of filtration by the type of trasport and general interests (popular events, active rest, beaches, museums, history, ski, etc.). There is another service «Tripmydream», where some filters can be used.

The third variant – usage of the services on the base of random proposals. Sometimes it works but not for all and not every time. We are talking about the sites, which randomly propose travels and tours. Typical examples is the site "Eightydays.me", which is searching service of air tours for the selected region.

As a result, if the user does not know where to go, does not want to work with the experts and wide filters or random offers do not help, then the improved system, which will help this specific segment of users to find and plan the trip is needed.

Literature review and task of the research

Nowadays there exist many systems, supporting users in the process of trips selection and passage of the needed stages, accompaning the realization of trip. In the paper «Automated Travel Planning» [1] the author Macin presents the algorithm for travel route planning but little attention is paid to the realization of the algorithm, especially regarding user`s interface. Besides, little information is available concerning the efficiency of the system in real conditions. In their turn, the authors of more recent paper «Smart Travel Planning System Using Machine Learning – A Review» [2] reveal rather actual approach to travel planning, using machine learning, however the paper is of survey character and reveals artificial intelligence as the interface to the formation of criteria and generation of the travel description, the importance of the input data quality and impossibility of step-by-step verification of the steps of the algorithm operation is underlined due to the hidden essence of the neural networks.

On the other hand, there exist methods, which can be used for offering travels on the base of preferences.

For instance, the solution of the problem of multicriterial optimization are convolutions, which can also be used for the filtration, rating, searching of the best variants, based on certain criteria.

Linear additive convolution calculates how many times certain strategy was optimal, it does not take into account the quantitative indices of the criteria values. Additive convobution is especially useful when the decrease of the assessment by one index is compensated by the increase of the assessment by another criterion or by several criteria [3]. It is easy to see that even by certain criteria the assessment equals zero, but other indices are better, total assessment will be satisfactory. Linear additive convolution with normalizing coefficients enables to work with quantitative criteria, which have different units as in the current case [4].

At weighted linear-additive convolution each criterion is multiplied by its own weight coefficient, then all the weighted criteria are summed and form weighted efficiency function, value of which is interprited as «quality coefficient» of the obtained solution [5]. The obtained scalarized function is maximized in the admissible range of limitations.

Multiplicative convolution is based on the postulate: low score at least by one criterion results in total low value. Thus, it can be stated that multiplicative convolution is based on the principle of fair compensation of the relative changes of the separate criteria. In this case there are two limitations: the sum of the weight coefficients must be equal and each of the weight coefficients must not be negative. The choice between the additive and multiplicative convolutions is determined by the importance of the account of the absolute or relative changes of certain criteria values.

Additive convolution is chosen over the multiplicative one because bad values for one of the criteria do not discredit the whole variant, as in case with multiplicative convolution [6].

Minimax convolution is the simplest method of constructing generalized criterion (supercriterion), based on the application of the minimax principle. Each of the criteria has its measurement and these measurements, as a rule do not coincide. That is why, first it is necessary to standardize all the available assessments. The drawback of max-min convolution is that it takes into account only the criteria which give the smallest values, all other criteria are ignored. Thus max min convolution is not often used, more often linear and multiplicative convolutions are used. But such approach always provide the result, which is minimal, below this value other values will not be obtained [7].

Then, in case of planning the trip, comprising several directions, it will be necessary to combine the variants by means of the combinations. Combination from n to k — it is the set of k elements, selected from the set of n dimension, where the order of elements is not taken into consideration. That is why, the combination, which differ only by the order of elements but not by the content are considered to be identical [8]. If the combinations are multiplied the cartesian product can be calculated [9].

If the travels are planned, which consist of several destinations, in this case the access to each combination must be obtained:

Traveling salesman – this is one of the most popular problems of combinatorial optimization, which consists of searching the most profitable route, which at least one time passes via the selected cities and then returns into the initial city.

While solving the problem, it is given: profitability of the route (the shortest, the cheapest, cumulative criterion, etc) and corresponding matrices of distance, cost. As a rule, it is noted that the route must pass across each city only once – in this case the choice is made by means of Hamiltonian paths. Hamiltonian path is a path, which includes each vertex of a graph only one time [10].

Traveling salesman problem may be presented in the form of graph, i. e., by means of vertices and edges between them. Vertices of the graph correspond to the cities and edges between vertices correspond to the paths between these cities. It can be stated that the solution of the problem is to find minimally weighted Hamiltonian path in the comple weighted graph [11].

One of the approaches to the solution of this problem is naïve approach, which calculates and compares all possible routes reshufflings for the determination of the shortest solution. It is necessary to calculate the distance of each route and select the shortest, which is the best solution.

Method of branches and boundaries divides the problem to be solved into several subproblems. This is the system for the solution of the series of subproblems, each of which may have several possible solutions and where the solution, chosen for one problem may influence the possible solutions of the next subproblems. For the solution of the problem it is necessary to choose the initial node and then set limited very large value. Then it is necessary to choose the cheapest arch between the unvisited and current node and add the distance to the current distance. The process must be repeated until the current distance becomes less than the limitation. If the current distance is less than the limited distance, the calculation may be completed. Now the distance may be added that the boundary be equal the current distance. This process is to be repeated until the whole path is covered [12].

Key to the nearest neighbor method is to visit always the nearest destionation point and then return to the first city, when all other cities will be visited. To solve the traveling salesman problem applying this method, it is necessary to choose the random city, find the nearest unvisited city and go there. When all the cities are visited, it is necessary to return to the first city [13].

Thus, the available methods were analyzed and their characteristic features were revealed.

On the base of the analysis of the problem, analogues and available methods the following task was formulated:

1. Use the methods of combinatorics for the creation of the combinations and solution of the traveling salesman problem for paths construction;
2. Elaborate the algorithm, using the linear additive convolution with weights and normalized values for variants evaluation;
3. Algorithm must be realized and integrated in Android program with the following functions:
   – installation of personalized settings;
   – installation of settings priorities;
   – display of offers.
4. Carry out the experiment, study the efficiency of the chosen methods by means of the experimental study of the algorithm, using the elaborated application and formulate the recommendation according to the results obtained.

Suggested algorithm

On the base of the above-mentioned methods new algorithm, based on the best of these methods is suggested.

The first step is rating and filtration of the countries and cities on the base of users preferences, by means of the linear additive convolution with the normalizing multipliers and weight coefficients. The list of settings may contain several parameters. The more settings are installed by the user, the more accurate the proposition will be.

Countries and then the cities should be evaluated in the following way: change the value to meet the requirement of optimization, determine Pareto set, normalize data, perform convolution.

As a result of the first step the potential list of countries and cities is obtained. The list is sorted by the rating, calculated by the method of linear additive convolution according to the users requirements.

The second step is merging of options. First, countries are merged in the needed for the user number of countries to visit, using combinatorics combinations. Then the cities of the chosen countries will be united in the same way. But in this case the multiplication of the combinations will be used.

Fot instance, one city of two in one country and one out of six cities in another country will lead to twelve combinations.

The result of the second step is the combination of the cities to visit within the frame of one trip.

The third step is the evaluation of the possible routes for each combination in case of planning trips, consisting of several destinations.

It is necessary to establish the order for visiting cities for each combination, taking into account both prices and distance. The price of the transfer and the distance between the cities will be equally important.

The result of the third step are better options of the directions for each combination with their ratings.

The last step is the assessment of all prepared combinations, applying the convolution with the normalizing coefficients.

The result of the last step is final assessment for each option. The best options will be presented to the user.

Special case of the algorithm is the situation when it is necessary to choose only one point of destination. In this case only the first step will be used with the selection of countries and cities.

Diagram of the activity [14] is shown in Fig. 1 for presentation of the suggested algorithm.

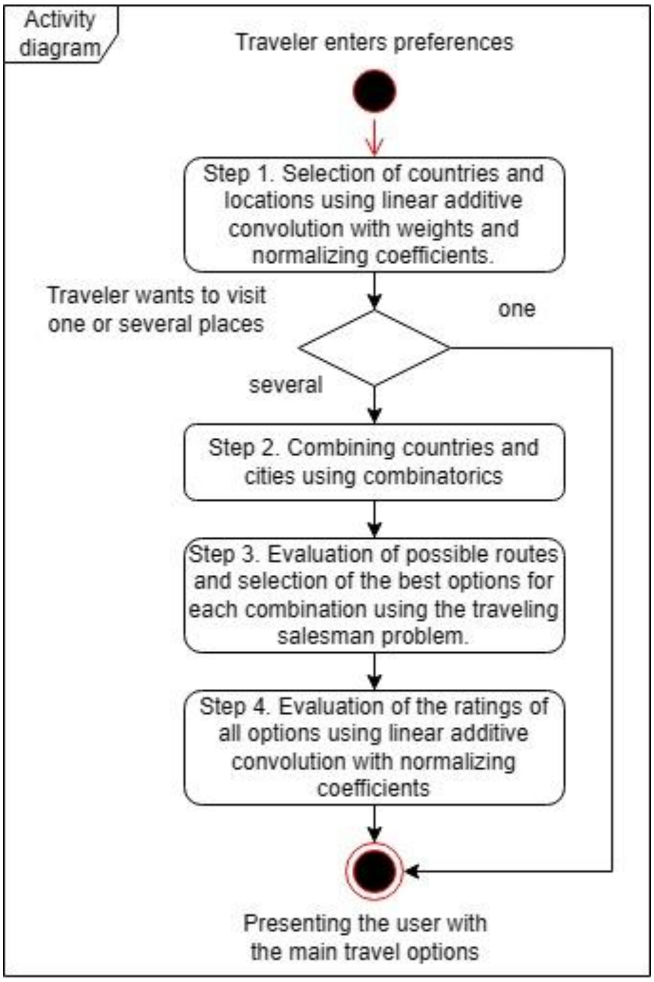

Fig. 1. Diagram of activity

Description of the experiment

Following the above-mentioned steps of the suggested algorithm the experiment will be carried out to confirm the proposed concept. However, the set situation and some stepts will be simplified for the demonstration sake.

For the first step it is necessary to choose possible countries to visit by the user. Suppose that there exists such set of alternatives: France, Italy, Czech Republic, Germany, Spain.

The value for each criterion for each country in given in Table 1, on the base of values, taken from the Internet.

Table 1

Value of the criteria for each country

Country	Temperature	Precipitation	Sea availability	Mountains availability	Daily rate
France	26	60	1	1	65
Italy	31	24	1	1	80
Czech Republic	26	85	0	0	22
Germany	24	81	1	0	32
Spain	29	27	1	1	50

Then it is necessary to reduce all the data to one principle of optimization – either maximization or minimization. Temperature, price and precipitation must be minimized. Thus, the values of sea and mountains parameters should be changed to obtain the same principle of optimization. Results of values change for the difference between maximum value and element is shown in Table 2.

Table 2

Reduced values to one optimization principle

Country	Temperature	Precipitation	Sea availability	Mountains availability	Daily rate
France	26	60	0	0	65
Italy	31	24	0	0	80
Czech Republic	26	85	1	1	22
Germany	24	81	0	1	32
Spain	29	27	0	0	50

Verification of Pareto set shows that all the alternatives are not worse than others at least by one criterion, i. e., any alternative can not be eliminated.

Now it is necessary to normalize the values . The following formula of maxmin normalization method will be used for this purpose:

$$x_{\text{normalized}} = \frac{x - \min(x)}{\max(x) - \min(x)}, \quad (1)$$

where *x* – is the value, being processed now, *min(x)* – is minimal value among all, *max(x)* – is maximum value among all.

The results of the calculations are presented in Table 3.

Table 3

Normalized values

Country	Temperature	Precipitation	Sea availability	Mountains availability	Daily rate
France	0.29	0.59	0	0	0.74
Italy	1	0	0	0	1
Czech Republic	0.29	1	1	1	0
Germany	0	0.93	0	1	0.17
Spain	0.71	0.05	0	0	0.48

Suppose that the user determined the following priorities for the criteria:

- f1 – average temperature in July – 0.2;
- f2 –precipitation in July – 0.1;
- f3 – sea availability – 0.3;
- f4 – mountains availability – 0.2;
- f5 – daily rate – 0.2.

The results of the calculations on the base of priorities, established by the user above, are presented in Table 4.

Table 4

Calculations for each country

Country	Calculations
France	0.2*0.29 + 0.1*0.59 + 0.3*0 + 0.2*0 + 0.2*0.74 = 0.265
Italy	0.2*1 + 0.1*0 + 0.3*0 + 0.2*0 + 0.2*1 = 0.4
Czech Republic	0.2*0.29 + 0.1*1 + 0.3*1 + 0.2*1 + 0.2*0 = 0.658
Germany	0.2*0 + 0.1*0.93 + 0.3*0 + 0.2*1 + 0.2*0.17=0.327
Spain	0.2*0.71 + 0.1*0.05 + 0.3*0 + 0.2*0 + 0.2*0.48=0.243

Consequently, Spain and France have better rating, that is why, for the demonstration experiment these countries are chosen.

Following the above-mentioned steps , cities in each country are chosen. Rating of Spanish cities is the following: first place – Barcelona, second place – Valencia, third place – Granada. Rating of French cities is the following: first place – Marseille, second place – Montpellier, third place – Nice. We pass to the second step of the suggested algorithm, which combines countries in the necessary for user number of countries to visit.

As in the current case for the demonstration only two countries were chosen, only one combination is accessible – Spain and France. But it is necessary to generate combinations for the chosen cities.

In the current experiment the user wishes to visit one city of each of two countries. Three cities are chosen from each country, then nine combinations will be created by means of multiplications of the co0mbinations.

The result with the list of the combinations of the cities is the folowwing: Barcelona in the combinations with every French city, the same for Valencia and Granada.

The third step – solution of the traveling salesman problem. First it is necessary to give the value of prices and directions in both destinations.

Distances between cities are based on the average values, taken from the Internet. Values of cities, which can not be in one route in the current case, for instance, Valencia and Barcelona are ommited. The value of the distance between the cities is normalized to be able to correspond correctly distances and prices. Prices for traveling from one city to another depend on the direction. As for the distances, the prices should be normaliuzed to be able to correspond them with with distances.

Results of the addition of normalized values of the price and distance for each city are shown in Table 5.

Table 5

Sum of the normalized values of the price and distance

City	Kharkiv	Barcelona	Valencia	Granada	Marseille	Montpellier	Nice
Kharkiv	–	1.25	1.44	1.84	1.23	1.71	1.1
Barcelona	1.22	–	–	–	0.2	0.45	0.15
Valencia	1.4	–	–	–	0.15	0.55	0.58
Granada	1.76	–	–	–	0.61	0.95	0.58
Marseille	1.16	0.14	0.12	0.54	–	–	–
Montpellier	1.51	0.4	0.48	0.9	–	–	–
Nice	1.08	0.12	0.5	0.62	–	–	–

On the base of the values, presented above, the travaling salesman problem is solved and the following list of the best routes for each combinations is obtained:

- T1: Kharkiv, Marseille, Barcelona, Kharkiv – 2.52;
- T2: Kharkiv, Barcelona, Montpellier, Kharkiv – 3.21;
- T3: Kharkiv, Nice, Barcelona, Kharkiv – 2.44;
- T4: Kharkiv, Marseille, Valencia, Kharkiv – 2.75;
- T5: Kharkiv, Valencia, Montpellier, Kharkiv – 3.5;
- T6: Kharkiv, Nice, Valencia, Kharkiv – 3;
- T7: Kharkiv, Marseille, Granada, Kharkiv – 3.53;
- T8: Kharkiv, Granada, Montpellier, Kharkiv – 4.3;
- T9: Kharkiv, Nice, Granada, Kharkiv – 3.48.

The fourth and the last step of the algorithm is the assessment of all prepared combinations, using linear additive convolution with normalized miltipliers. Weight is not considered as all three categories – rating of traveling saleman problem, rating of the Spanish city, rating of the French city – are equally important.

All the assessments of the best options from the previous step are collected and are placed into the column of the traveling salesman problem assessment. Ratings of the cities are taken from the first step of the algorithm. All the above-mentioned ratings are shown in Table 6.

In this case all the data are reduced to minimum, that is why, at the present moment the data should not be corrected. Values must be normalized by means of the formula 1. Results are shown in Table 7.

As it was noted above, all the criteria are equally important, that is why, weight coefficients are not applied. The results of the linear convolution: T1 – 0.04, T2 – 0.91, T3 – 1, T4 – 0.56, T5 – 1.57, T6 – 1.8, T7 – 1.59, T8 – 2.5, T9 – 2.56.

Table 6

Three ratings for each combination

Variants	Assessment of traveling salesman problem	Rating of the Spanish city	Rating of the French city
T1	2.52	1	1
T2	3.21	1	2
T3	2.44	1	3
T4	2.75	2	1
T5	3.5	2	2
T6	3	2	3
T7	3.53	3	1
T8	4.3	3	2
T9	3.48	3	3

Table 7

Normalized values

Variants	Assessment of traveling salesman problem	Rating of the Spanish city	Rating of the French city
T1	0.04	0	0
T2	0.41	0	0.5
T3	0	0	1
T4	0.16	0.5	0
T5	0.57	0.5	0.5
T6	0.3	0.5	1
T7	0.59	1	0
T8	1	1	0.5
T9	0.56	1	1

Therefore the best variants of the travelling are :

- T1: Kharkiv, Marseille, Barcelona;
- T4: Kharkiv, Marseille, Valencia;
- T2: Kharkiv, Barcelona, Montpellier.

Thus , the experiment was carried out, performing the steps of the suggested algorith.

For the assessment of the efficiency and performance of the suggested algorithm severaral experiments were carried out, using various matrices. Experiments were carried out at operation system Android, device Samsung Galaxy S8, which has the processor Exynos 8895 with 8 cores, 4 GB of RAM (random access memory) and memory operation system Android 7.0 (Nougat).

We will perform N = 5 launches of the algorithm on the sets of data of various volume (10, 20, 50 and 100 cities from one and different countries) for obtaining indices of execution time, presented in the Table 8.

Table 8

Execution time of the algorithm

Number of cities	Average execution time (sec)	Minimal execution time (sec)	Maximal execution time (sec)
10	0.5	0.45	0.55
20	1.2	1.1	1.3
50	3.5	3.3	3.7
100	7.8	7.5	8.1

Results showed that the execution time of the algorithm is within the limits which meet the requirements of potential users, even if the volume of data increases.

Monitoring of loading on the central processor during execution time of the algorithm showed the usage of the resources is in addmissible measures. During the experiment any applications were launched and the system was in "flying" mode, to decrease the impact of factors. Results of the experiment are presented in Table 9.

Table 9

Loading on central processor

Number of cities	Average loading on CPU (%)	Minimal loading on CPU (%)	Maximum loading on CPU (%)
10	14	11	17
20	15.5	13	18
50	17.5	15	20
100	27.5	26	29

It was revealea that the processing of larger volumes of data requires more time but it does not lead to critical loading of the system.

Program realization

Algorithm is realized by means of programming language Kotlin. Mobile program for Android was developed as the user`s interface, using Kotlin.

Both algorithm and the application were developed according to the best principles of software development, including principles of clean architecture [15].

For the demonstration of the user`s experience in the developed application the screenshorts are added. First – the initial screen where the users must indicate their preferences regarding the country, city, climate, precipitation, mountains proximity, sea proximity , maximum daily rate, initial city and proceeding of what to choose the route-price, distance or both.

The second screen provides the possibility to establish the priority of preferences, dragging the criteria to establish order from the most desirable to least desirable

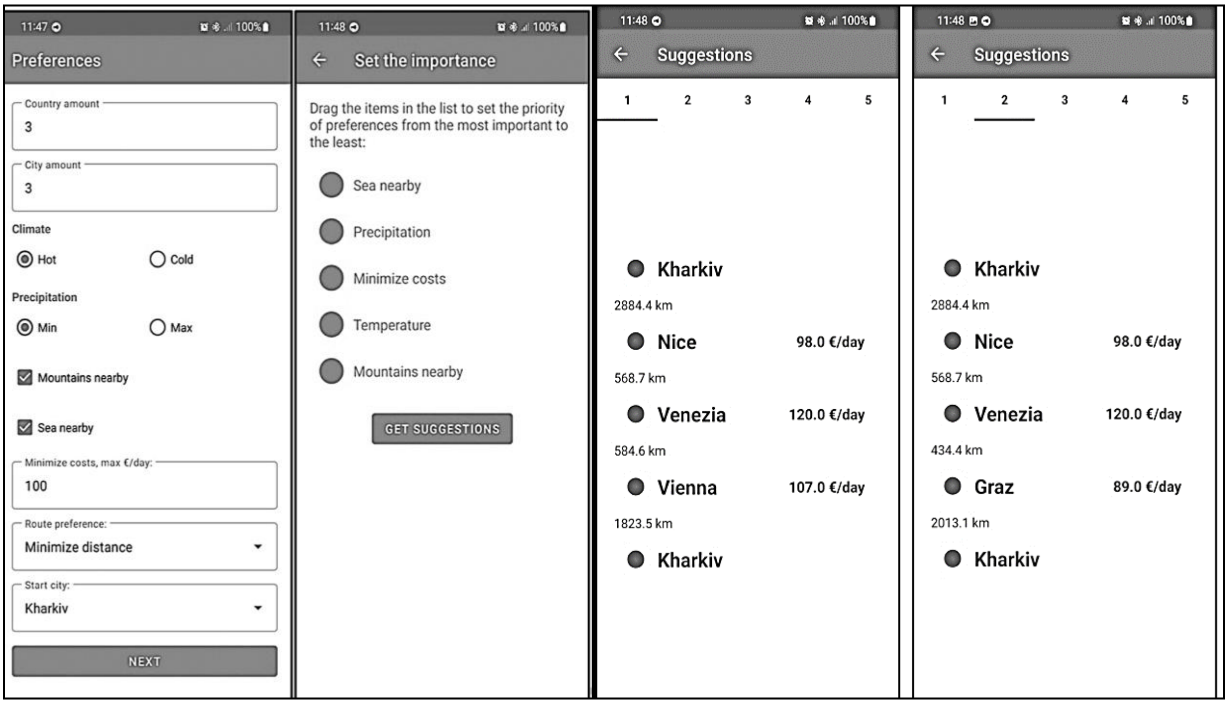

Fig. 2.Screenshorts of the user, priority setup and the suggested travelings

Thus, the operation of the program realization of travelings suggestion algorithm was demonstrated.

Conclusions

The problem is that the travelings, especially those which include several cities, countries to visit, should be proposed to the user on the base of their preferences. The more setups the user installs, the more accurate decision will be proposed.

Available services, connected with traveling were analyzed, it was revealed that greater part of them do not have the possibility to suggest such travelings or services have other problems. Available methods are reconsidered, improved algorithm, based on the following methods is developed: linear additive convolution with normalized coefficients and weights, methods of combinatorics, traveling salesman problem. After development of the algorithm the experiment was carried out to prove that the suggested algorithm works in a proper way. Operation rate and loading on the CPU depending on the number of the input data were analyzed, satysfying results were obtained.

Concerning further research and improvements is account of all available methods of transporting for the given route and suggestion of the exact number of days for each city or other point of destination. The suggested algorithm can be used in practice, integrating it in the software for tourist companies.

REFERENCES

1. Nagrodkiewicz Piotr. Automated Travel Planning / Piotr Nagrodkiewicz, Marcin Paprzycki // Research Gate. – 2005. – P. 1 – 12. DOI: 10.1109/ITICT.2005.12345.

2. Varghese A. Smart Travel Planning System Using Machine Learning – A Review / Alex Varghese, Amal Santhosh, Badhusha TE, Fayiz Jalal, Shameena EM // International Journal of Research Publication and Reviews. – 2023. – Vol. 4, №. 5. – P. 123 – 134. DOI: 10.12345/ijrpr.2023.123456.

3. Zgurovsky M. Z. Introduction. In: Combinatorial Optimization Problems in Planning and Decision Making. Studies in Systems, Decision and Control [Text] / Mykhailo Zgurovsky, Alexander Pavlov // Springer, Cham. – 2019. – vol. 173. – P. 1 – 14. DOI: 10.1007/978-3-319-98977-8_1.

4. A study of optimization models for creation of artificial intelligence for the computer game in the tower defense genre / O. Mazurova, O. Samantsov, O. Topchii [et al.] // 2020 IEEE international conference on problems of infocommunications. science and technology (PIC S&T), Kharkiv, Ukraine, 6 – 9 October 2020. – Kharkiv, 2020. – P. 491 – 496. DOI: 10.1109/picst51311.2020.9468057.

5. Vakhania N. Multicriteria Optimization – Pareto-Optimality and Threshold-Optimality / N. Vakhania, F. Werner // IntechOpen. – 2020. – P. 106. DOI: 10.5772/intechopen.78897.

6. Misyurin S. Multicriteria Optimization of a Dynamic System by Methods of the Theories of Similarity and Criteria Importance / Sergey Misyurin // Mathematics. – 2021. – Vol. 9, №. 22. – P. 2854. DOI: 10.3390/math9222854.

7. Nelyubin A. P. Multicriteria choice based on criteria importance methods with uncertain preference information / A. P. Nelyubin, V. V. Podinovski // Computational Mathematics and Mathematical Physics. – 2017. – Vol. 57, № 9. – P. 1475 – 1483. DOI: 10.1134/s0965542517090093.

8. Sagan B. Combinatorics: The Art of Counting / B. Sagan. – Providence, United States, 2020. – 304 p.

9. Shao Z. Matching Book Embedding of the Cartesian Product of a Complete Graph and a Cycle / Shao Zeling, Liu Yanqing, Li Zhiguo // arXiv: Combinatorics. – 2020. – P. 89 – 97. DOI: 10.48550/arXiv.2002.00309.

10. Davendra D. Introductory Chapter: Traveling Salesman Problem – An Overview / Donald Davendra, Magdalena Bialic-Davendra // Novel Trends in the Traveling Salesman Problem. – 2020. – P.1 – 6. DOI: 10.5772/intechopen.94435.

11. Hossain S. An Efficient Solution to Travelling Salesman Problem using Genetic Algorithm with Modified Crossover Operator / Md Sabir Hossain // Emitter International Journal of Engineering Technology. – 2019. – Vol. 7, № 2. – P. 480 – 493. DOI: 10.24003/emitter.v7i2.380.

12. Mahfoudh S. S. A branch and bound algorithm for the porbabilistic traveling salesman problem / Soumaya Sassi Mahfoudh, Walid Khaznaji, Monia Bellalouna // 2015 IEEE/ACIS 16th International Conference on Software Engineering, Artificial Intelligence, Networking and Parallel/Distributed Computing (SNPD), Takamatsu. – Takamatsu, 2015. – P. 6567 – 6581. DOI: 10.1109/snpd.2015.7176284.

13. Towards Comparative Analysis Of Branch - And - Bound And Nearest Neighbour Algorithms / J. A. Ayoola, E. O. Asani, A. E. Okeyinka [et al.] // 2020 International Conference in Mathematics, Computer Engineering and Computer Science, Ayobo, Ipaja, Lagos, Nigeria, 18–21 March 2020. – Ayobo, 2020. – P. 1 – 5. DOI: 10.1109/icmcecs47690.2020.240901.

14. Osis J. Topological UML Modeling: An Improved Approach for Domain Modeling and Software Development / Janis Osis, Uldis Donins // Elsevier Science & Technology Books, 2017. – 276 p.

15. Martin R. Clean Architecture: A Craftsman's Guide to Software Structure and Design / Robert Martin – Pearson, 2017. – 432 p.

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