Design of personalized city tourist trips

Diseño de viajes turísticos personalizados a la ciudad

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Abstract

In this article we propose a mathematical model to design personalized tourist trips around the city. Suppose you are a tourist who wants to visit specific tourist places, and you have some time available to do it. Due to the closeness and/or available time could be possible to visit another interest points, but you do not know how to perform it. So, you want to have a "route" of tourist places including those places you want to visit and that minimizing the total travel time. Also, it is possible to indicate the start and end points in the route, being the end equal to the starting point or not. We show how this can be modelized as a combinatorial optimization problem, called vehicle routing problem (VRP). Where the "route" will be the personalized plan of points of interest to visit. This plan can be design for one or several days, also considering the walking time you want to do during the tour, and the use of different means of transportation.

City Trip Planner, user preferences, MIP model, routing, VRP

Resumen

En este artículo proponemos un modelo matemático para diseñar viajes turísticos personalizados por la ciudad. Suponga que es un turista que quiere visitar sitios turísticos específicos y tiene un tiempo disponible para hacerlo. Dada la cercanía y/o tiempo disponible, es posible visitar otros puntos de interés, pero no sabe cómo realizarlo. Así, que desea tener una "ruta" de lugares turísticos que incluya aquellos lugares que desea visitar y que minimicen el tiempo total de recorrido. Además, es posible indicar los puntos inicial y final de la ruta, siendo el final igual al de inicio o no. Nosotros mostramos cómo esto puede ser modelizado como un problema de optimización combinatoria, llamado problema de enrutamiento de vehículos (VRP). En donde la "ruta" será el plan personalizado de puntos de interés a visitar. Este plan puede ser diseñado para uno o varios días, considerando también el tiempo caminando que desee realizar su recorrido, y el uso de diferentes medios de transporte..

Planificación de viaje en ciudad, Preferencias de usuario, Modelo MIP, Ruteo, VRP

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Introduction

In this article we show how the problem of design of personalized city tourist trips designing can be modeled as a vehicle routing problem (VRP) (Toth,P, & Vigo, D., 2014).

The vehicle routing problem (VRP) is a problem of combinatorial optimization and integer programming what question "What is the optimal set of routes for a fleet of vehicles that must meet the demands of a set given of clients?" It is a generalization of the well-known Problem of Traveling (TSP) (Flood, 1956).

The problem of design of personalized city tourist trips we define as follows:

You have a tourist who wants to visit some tourist places or interest points, this has a set of preferences when selecting the places to visit, such as:

1) The time available to travel,
2) The inclusion in the plan (tourist trip) of those tourist places you wish to visit,
3) The possibility of visiting other tourist places that are close to the points of interest indicated,
4) The alternative of establishing a starting point of travel and a final point, where they are not necessarily the same,
5) The advantage of having a plan for one or several days,
6) The option to determine the time you want to make your walking tour (minimum and maximum time), and,
7) The option of using the subway as transportation.

The remainder of this document is organized as follows: A review of the literature related to the problem is presented, methodology used, mathematical formulation, results, conclusions and references.

Literature Review

In the literature we find works that aim to generate tourist routes such as (Cergibozan Ç. & Tasan A.S., 2018), (Vansteenwegen, et. al, 2011), (Garcia, et. al, 2010), however, the objective function is defined in maximizing user satisfaction, defining a score for each site of interest to visit. Finally, the route obtained is subject to selecting those sites that had a higher score.

However, when a tourist visit a city usually have knowledge beforehand of the popular typical places would like to visit. If he has one or several days that he can arrange to make the visits, the problem would be to decide in what way he will travel to include those tourist places and if possible, some that are close to them, to optimize the total time available.

(Borràs, 2014) and (Gavalas, 2014) they carry out a review of the state of the art of the Systems of Recommendation (RS), in tourism. In which both the modeling of the problem, the modeled characteristics and the methodologies used are very varied.

Some methodologies such as *Artificial Intelligence Planning* have been used to represent the problem of personalized city tourist trips (Elizalde, R., et al., 2017), and although they are efficient in finding personalized routes for tourists, the solutions found are not optimal.

In fact, due to the complexity of solving some problems related to the personalization of tourist routes and the large number of works with different characteristics, in the literature it has been chosen to use other non-exact techniques such as genetic algorithms (Maruyama, 2004), guided local search (Wouter, 2008), among many others. It is important to know the scope of this formulation, because as future research we want to improve our solutions implementing another kind of algorithms and techniques more effective.

Methodology

In order to know optimal solutions and its properties by the tourist city trip design problem, we develop a mathematical formulation similar to the Vehicle Routing Problem. The Vehicle Routing Problem (VRP) calls for the determination of the optimal set of routes to be performed by a fleet of vehicles to serve a given set of customers, and it is one of the most important, and studied, combinatorial optimization problems (Toth, P., & Vigo, D., 2014)

We can say that our mathematical modeling is like a VRP, because the routes of the vehicles of the routing problem are as the route plan provided for the tourist to visit tourist places or interest points in a city, and the clients that these vehicles must serve, as the points of interest to visit.

So, the route resulted is a plan that a tourist can follow to make his tourist tour in a city.

Mathematical formulation

We consider a general form on a weighted, symmetric and directed graph $G = (V, A)$, where V is the set of nodes and A is the set of arcs. Let P a set of interest points in a certain city, in this version of the problem, we suppose that the start and end in a route is an interest point, so, we have that all our vertices as $V = P$. Let M the set of transportation line (walking, metro), D the set of days (routes) available by the tourist and R the set of sites that the tourist wants to include strictly in the tour plan. We have next parameters and decision variables:

Parameters:

tv_i: time spend to visit the site $i \in P$,
$tt_{i,j}^{m}$: travel time between nodes i and j, $(i,j) \in A$, using the transportation line $m \in M$,
s_d: point to start the trip in the day $d \in D$,
e_d : point to end the trip in the day $d \in D$,
f_d: 1 if the route is close (start and end are the same) and 0 if is open (start and end are different),
T_d: available time of the tourist at day $d \in D$,
TMw_d: maximum time that the tourist wants to walk at day $d \in D$,
Tmw_d: minimum time that the tourist wants to walk at day $d \in D$,

Decision variables:We define x_{ij}^{dm} as binary variable that is equal to 1 if in the day d the tourist uses arc (i,j) in transportation line m, y_p^d equal to 1 if the interest point p is visited in the day d.

With the above notation, our problem can be formulated as:

$$min \sum_{d\in D} \sum_{m\in M} \sum_{(i,j)\in V} tt_{ij}^{m}\, x_{ij}^{dm} \quad (1)$$

$$\sum_{(i,j)\in\delta^{-}(i)} \sum_{m} x_{i,j}^{d,m} = y_i^d \quad i \in V\backslash\{s,e\},\ d \in D \quad (2)$$

$$\sum_{(i,j)\in\delta^{+}(i)} \sum_{m} x_{i,j}^{d,m} = y_i^d \quad i \in V\backslash\{s,e\},\ d \in D \quad (3)$$

$$\sum_{p\in P} tv_p y_p^d + \sum_{m\in M} \sum_{(i,j)\in V} tt_{i,j}^{m}\, x_{i,j}^{d,m} \leq T_d,\ \ d \in D \quad (4)$$

$$\sum_{m\in M} \sum_{j\in V} x_{s,j}^{d,m} + \sum_{m\in M} \sum_{j\in V} x_{j,e}^{d,m} = 2,\ d \in D \quad (5)$$

$$\sum_{m\in M} \sum_{j\in V} x_{j,s}^{d,m} = (1 - f_d),\ d \in D \quad (6)$$

$$\sum_{m\in M} \sum_{j\in V} x_{e,j}^{d,m} = (1 - f_d),\ d \in D \quad (7)$$

$$\sum_{d\in D} y_r^d = 1,\ r \in R \quad (8)$$

$$\sum_{d\in D} y_i^d \leq 1,\ \ i \in V\backslash R \quad (9)$$

$$\sum_{(i,j)\in V} tt_{i,j}^{1} x_{i,j}^{d,1} \leq TMW_d,\ d \in D \quad (10)$$

$$\sum_{(i,j)\in V} tt_{i,j}^{1} x_{i,j}^{d,1} \geq Tmw_d,\ d \in D \quad (11)$$

$$\sum_{i\in s, j\notin s} x_{i,j}^{d,m} \leq y_r^d/|S|, S \in V\backslash\{s,e\}, 2 \leq |S| \leq |V-2|/2, r \in R \quad (12)$$

The objective function (1) find to minimize the total transportation time in each day by the tourist. Constraints (2) and (3) enforce that for each node can be just one 'in-arc' and one 'out-arc' if the touristic place is visited. (4) indicates that the total time (transportation and visit time) available by day cannot be exceeded. With constraints (5)-(7) we relate the in-degree by start and end points. Constraints (8) include in the tour all the points that the tourist wishes to visit, and (9) help us to does not visit a site if that was visited in previous days. To consider the maximum and minimum time the tourist wants to walk we have (10)-(11) and finally, constraints (12) are the well knows subtour elimination constraints adapted for our problem, in this case we need to model these considering the directed form.

Results

The Mathematical formulation was implemented using OPL Optimization Version 12.5, tests were run on Intel Core i7 Gaz with 16 GB.

Instance characteristics

Our instances are inspired to visit Barcelona considering $|P| = \{10,15,20\}$ Two kind of transportation lines M was selected, walking and metro, due to the main interest points in Barcelona are well connected only using metro lines. But, the model can be well adapted to include more transportation lines as bus and tram. To calculate the visit time in each point, we use the tourist information provided by the tourism of Barcelona. About the times tt_{ij}^{m}, we estimated that using google maps, and times with metro, we selected the minimum transfer time between interest points.

– **10 interest points**

Instance 1:

Figure 1 Instance

– The tourist will visit…

Day: 1-
2-> Ramblas
7-> Camp Nou Stadium Stadium

Day: 2-
8-> Gràcia
9-> Park Güel
10-> Sagrada Familia

With total visit time: 310 min.

The tourist will travel:

Day: 1
in line 1 (walking) 1 - 2, 7-1
in line 2 (metro) 2-7

At day 2
in line 1 (walking) 8 -10-1
in line 2 (metro) 1 – 9 - 8

With total travel time: 126 min.

Instance 2:

Testing with an open route, the tourist has 2 available days and he want start at "1-Ramblas" and to end in "4-Barceloneta. In the planning must be 7-Camp Nou Stadium, 9-Park Güel 10-Sagrada Familia. Respect to the times, we have next table.

The solution is:
The tourist will visit:

Day: 1
2->Ramblas
3->Gotic Quather

Day: 2-
5 ->Columbus monument
7 -> Camp Nou Stadium Stadium
9 -> Park Güel
10 -> Sagrada Familia

With a visit time: 355 min.

The tourist will travel:

Day 1
in line 1 (walking)
1 - 2 – 3 - 4
Day 2
in line 1 (walking)
5 – 4, 9 - 10

in line 2 (metro)
1 – 9, 7 – 5, 10 - 7
With a total travel time: 124 min.

– **15 interest points**

Instance 1:

This open route is starting at "8-Gracia"and end at "1-Ramblas". In the planning must 10-Sagrada Familia, 6-Magic Font, 3-Gotich Quather and 5-Columbus monument. In table "" we have the times by this instance.

The tourist will visit:

Day: 1-
2->Ramblas
3->Gotic Quarther

Day: 2-
5-> Columbus monument
6-> Magic Font
7-> Camp Nou Stadium
10-> Sagrada Familia

With visit time:335 min.

The tourist will travel:

Day 1
in line 1(walking) 4 - 3
in line 2(metro) 3 - 2
in line 1(walking) 2 - 4

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Day 2

in line 1(walking) (4, 10) = 14
in line 2(metro) (10, 6) = 1
in line 1(walking) (6, 7) = 1
in line 2(metro) (7, 5) = 1
in line 1(walking) (5, 4) = 1

With a travel time: 168 min.

– **Instrance 2:**

The close route is starting at “4-Barceloneta”. In the planning must be 7- Camp Nou Stadium, 9-Park Güel 10-Sagrada Familia. In table “” we have the times by this instance.

The tourist will visit:

Day: 1-
2->Ramblas
3->Gotic Quarther

Day: 2-
5-> Columbus monument
6-> Magic Font
7-> Camp Nou Stadium
10-> Sagrada Familia

With visit time:335 min.

The tourist will travel:

Day 1
in line 1(walking) 4 - 3
in line 2(metro) 3 - 2
in line 1(walking) 2 - 4

Day 2
in line 1(walking) 4 - 10
in line 2(metro) 10 - 6
in line 1(walking) 6 - 7
in line 2(metro) 7 – 5
in line 1(walking) 5 - 4

With a travel time: 168 min.

	n10_1		n10_2		n15_1		n15_2	
Available time	300	600	600	600	360	480	660	660
Max. time walking	120	180	120	180	120	180	120	180
Min. time walking	60	60	60	60	30	120	60	120

Table 1 Times instances BCN_N10-N20 (min)

In general, by instances BCN_N10-N20 solving times are between 10-70 secs, these times are such fast and reasonable in this kind of problems. By another hand, our problem is complex when the number of nodes growth. We will see that in next results.

– **20 interest points**

With these instances, model only is able to get solutions with 24-21% optimality gap. Down, we can see the characteristics by the three instances tested and the obtained gaps.

	1	2	3
R	2	6	2
K	2	2	2
D	1	1	0
S	1	1	1
E	7	7	1

Table 2 Parameters by instances BCN_N20

Instance	gap(%)
BCN_N20_1	21.06
BCN_N20_2	23.81
BCN_N20_3	21.44

Table 3 Results instances 20 interest points

Conclusions

In this paper, we presented a VRP model to represent the problem Design of Personalized City Tourist Trips. Where a set of characteristics are considered: time available, tourist places that I wish to visit, visit to nearby places, start and end of route, planning several days, walking time, use of subway.

Using OPL/Cplex optimizer, some small instances and two kind of transportation lines (walking and metro) applied to Barcelona city were tested. By instances with 10-15 nodes it is possible to get solution in reasonable time, but with 20 nodes onwards our problem is intractable.

As future work we want to implement a Branch & Cut algorithm and to strengthen this formulation, because actually all subsets $S \subset V$ are generated with OPL and it is a determining factor for not obtaining the results with the instances of 20 nodes (or more). Also, we consider implementing this methodology in software available and interactive to users, as a mobile application or a web site.

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