Optimization Final Project

Topic: Bar Hopping

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Abstract

Bar hopping is an organized event in which a group of people visit multiple bars in one night. Bar hopping can be arranged by coalitions of venues, charities, or other organizations. In order to form a bar hopping to raise money for an organization, one needs to gather as many participants as possible. The event is held in an area where there are many venues within a safe walking distance and volunteers serve as designated drivers. With this optimization model, we try to find out the best possible route which maximizes the profits/benefits that can be earned from this event while sticking to a pre-determined budget.

Contents

Introduction

A bar hopping is the act of drinking in multiple pubs or bars in a single night. This activity is organized across the globe, and it serves as social gatherings for local expatriates and tourists. Bar hopping are generally spontaneous nights out in which the participants arrange to meet somewhere and decide over drinks where to drink next. Structured routes with regular stops are rare. Most outings based around a special occasion such as a birthday involve a pub hopping, often with the group splitting up but agreeing on meeting at the next location. It is a common to see several groups orbiting the various drinking locations with little apparent coherence or structure.

In the north of Spain, around the Basque Country, the tradition for groups of male friends hopping pubs and drinking a short glass of wine at each pub, and often singing traditional songs, is known as txikiteo or chiquiteo, and can be held at night or day. By the end of the 20th century, it was extended also to women, and when it involves a wider variety of drinks, it is more often called poteo.

One of the versions of bar hopping is blended with charity, in which people drink across various bars in a well-defined area to collect maximum benefits for charity. More the number of people, more would be the amount of charity. Some organizations host this event in which an agreement is made with bars that whatever revenue would be generated from the event, a part of that would be donated for charity. People register for the event and participate so that they can actively contribute to the cause.

In this project, we have introduced an optimization model that would be beneficial in determining the most efficient route for participants to maximize the amount of charity that can be generated by visiting different bars with minimum distance travelled. It is not viable to visit all the places in a single night because there are a lot of constraints that would restrict the activity such as budget per person, time etc. We will be taking these constraints into consideration while building the model.

In the Travelling Salesman Problem, we figure out the most efficient route that minimizes the total distance that the salesman travels in a particular journey. Our optimization model is a special case of the Travelling Salesman Problem. An additional feature accompanied in this model is the benefit or profit associated with the bar to be visited and its maximization. After defining the model, we have taken real-world data of 10 bars in the Cincinnati area and seen how the model would perform in case a bar hopping event is organized in across these bars.

Literature Review

In the Travelling Salesman Problem (TSP), the objective is to visit each location and return to the starting point, while minimizing the total distance covered. There is no benefit or value attached with visiting a particular location. However, in the bar hopping problem, there is an element of benefit associated with visiting each bar. Hence, the TSP problem is now transformed into a travelling salesman problem with profits. TSP with profits may be seen as bi-criteria; with two opposite objectives. One objective is to push the salesman to travel in a way that maximizes the profits and the other objective is to minimize travel costs or budget costs with the right to drop vertices.

Viewed in this light, solving TSPs with profits should result in finding a non-inferior solution set, i.e., a set of feasible solutions such that neither objective can be improved without deteriorating the other. The first attempts to solve the bi-criteria problem were made by Keller in 1985 and Keller and Goodchild in 1988 who call it the multi-objective vending problem, but their versions contain of sequentially solving single-criterion versions of the problem.

In case of bar hopping, it is unlikely that every location i.e. every bar will be visited and since there is a profit associated, the decision may vary. Hence, our objective would be to maximize the profits which can be optimized by visiting the pubs associated with maximum profits and reducing the travel costs during the visits. The overall goal is simultaneous optimization of the collected profit and travel costs. One thing that we have assumed here is that the start and end location of the tour will be same.

TSP with profits can be further classified into three variants as explained –

1. **Profitable Tour:** In such problems, the objective is to find a tour that minimizes the travel costs minus the collected profit.
2. **Orienteering:** In such problems, the objective is to find a tour that maximizes the profits collected provided the travel costs don't exceed a specified limit.
3. **Prize collecting:** In such problems, the objective is to find a tour that minimizes travel costs provided the collected profits are not less than a specified amount.

The bar hopping problem can be classified into any of the three variants but since college students are normally budget constrained, so we will specify a budget to the problem. Also, there is no limitation on specifying a starting and ending point well in advance. Therefore, we have used the profitable tour variant for our study.

Problem Statement

We shall now explain the problem with parameters, decision variables and an objective function which will be subjected to some constraints in order to get the maximum benefits or profits. We have a set of 10 Bars which are defined as Nodes which can be visited or not visited depending upon the benefits associated. We have a set of Arcs which defines parameters like whether we need to travel from one node to another or not and the distance associated when we travel from one node to another. There is a benefit and cost of visiting each node i.e. the cost of one drink at a pub. We also have a budget constraint which we cannot exceed.

The objective function is to identify a tour through a subset of nodes which maximizes the collected benefits minus the distance travelled/walked subject to maximum available budget for drinks. Also, since we are computing the benefits collected and distance travelled in different units, we will be including a factor which is called the weighting parameter denoted by α to balance both variables. We shall now formulate a general mathematical model to compute the problem which we will solve further using a real-world dataset.

Mathematical Formulation

In this section, we have proposed a general model for the problem.

Sets associated with the problem:

We have a set of Nodes, $N = \{1,2,3, \ldots., 10\}$

We have a set of Arcs, $A = \{(i, j) : i \in N, j \in N, i \neq j\}$

Decision Variables

To know whether we are visiting a bar, we have created a node and if we are travelling that distance, for that we have an arc.

$x_{ij} = 1$ if we select arc (i,j), 0 otherwise $\forall$ (i,j) $\in$ A

$y_j = 1$ if node j is included in the tour, 0 otherwise $\forall$ j $\in$ N

Parameters

The parameters are various features that are associated with the model which help us identify the absolute values. These are mostly fixed or constant terms that have been pre-determined.

α = Weighting value for objective function
d_{ij} = Distance between nodes i and j, $\forall\ (i,j) \in A$
b_j = Benefit associated with a drink at node j, $\forall\ j \in N$
c_j = Cost of one drink at node j, $\forall\ j \in N$
B = Maximum available budget

Objective Function

The objective function is what we must achieve from this model which is subjected to a few constraints that we have to keep in mind while computing the results. Any violation of the constraints is strictly prohibited since this won't give us the fruitful results we are expecting from the model.

$\text{Max} \sum_{j\in N} b_j y_j - \alpha * \sum_{(i,j)\in A} d_{ij} x_{ij}$

s.t

<u>Exiting a node constraint-</u>

$\sum_{(i,j)\in A} x_{ij} - y_j = 0, \forall\ i \in N$

<u>Entering a node constraint-</u>

$\sum_{(j,i)\in A} x_{ji} - y_j = 0, \forall\ j \in N$

<u>Budget constraint-</u>

$\sum_{j\in N} c_j y_j \leq B$

<u>Subtour elimination constraint-</u>

$\sum_{i\in S} \sum_{j\in S} xij \leq |S|-1, \forall\ S \subseteq N, 2 \leq |S| \leq |N|-1$

Once we have explained the general formulation of our model, we would be requiring a solver in which we can input the variables, constraints to attain our objective. We shall be using the AMPL model to solve the problem that we have defined.

AMPL Model

This is the AMPL model that we have used for a small instance of the bar hopping optimization problem. This model includes constraints to eliminate two-cycles and constraints to eliminate three-cycles (when necessary).We shall now input the decision variables, objective function, and constraints of the Cincinnati bars data that we have collected into the AMPL model to get the required output. Below is the formulation that we have used to input our data into AMPL.

Sets:

```
set N
set LINKS := {i in N, j in N: i <> j};
```

Parameters:

```
param alpha >= 0;
param d{LINKS} >= 0;
param b{N} >= 0; #default benefit of visiting a bar
param c{N} >= 0; # default cost of one drink

param B default 30; # default maximum budgets for drinks
```

Decision Variables:

```
var x{LINKS} binary;

var y{j in N} binary;
```

Objective Function:

```
maximize benefit_minus_distance:
sum{j in N} b[j]*y[j] - alpha*sum{(i,j) in LINKS} d[i,j]*x[i,j];
```

Constraints:

```
subject to exit{i in N}:
sum{(i,j) in LINKS} x[i,j] - y[i] = 0;

subject to enter{j in N}:
sum{(i,j) in LINKS} x[i,j] - y[j] = 0;

subject to budget:
sum{j in N} c[j]*y[j] <= B;

subject to two_cycles{(i,j) in LINKS}:
x[i,j] + x[j,i] <= 1;

subject to three_cycles{(i,j) in LINKS, k in N: i <> k and j <> k}:
x[i,j] + x[j,k] + x[k,i] <= 2;
```

Model Validation

Data

set N = 1 2 3 4 5 6 7 8 9 10

param alpha = 0.5;
param bonus = 1 550 2 600 3 450 4 650 5 700 6 800 7 1000 8 250 9 850 10 750;
param c = 1 4 2 4 3 4 4 5 5 5 6 4 7 6 8 4 9 5 10 5;
param d = 1 2 3 4 5 6 7 8 9 10;

Distance matrix(in meters):

1	.	300	420	430	768	900	235	546	456	430
2	300	.	345	200	250	545	700	250	500	320
3	420	345	.	100	750	225	525	300	650	200
4	430	200	100	.	250	300	200	220	515	100
5	768	250	750	250	.	220	350	450	300	350
6	900	545	225	300	220	.	300	225	450	250
7	235	700	525	200	350	300	.	550	345	200
8	546	250	300	220	450	225	550	.	435	625
9	456	500	650	515	300	450	345	435	.	300
10	430	320	200	100	350	250	200	625	300	.

Command

Solve:

display x, y;

AMPL Output

On solving this model using AMPL-Gurobi, we obtain the following output:

100 variables, all binary. 831 constraints, all linear; 2550 non zeros

20 equality constraints, 811 inequality constraints

1 linear objective; 100 non zeros.

Gurobi 9.1.2: threads=4

Gurobi 9.1.2: optimal solution; objective 4042.5

28 simplex iterations

```
x [*,*]
:   1  2  3  4  5  6  7  8  9 10
1   .  0  0  0  0  0  0  0  0  0
2   0  .  0  0  0  0  0  0  0  0
3   0  0  .  0  0  0  0  0  0  0
4   0  0  0  .  0  0  0  0  0  1
5   0  0  0  0  .  0  0  0  1  0
6   0  0  0  0  1  .  0  0  0  0
7   0  0  0  1  0  0  .  0  0  0
8   0  0  0  0  0  0  0  .  0  0
9   0  0  0  0  0  0  1  0  .  0
10  0  0  0  0  0  1  0  0  0  .
;
```

```
y [*] :=
 1  0
 2  0
 3  0
 4  1
 5  1
 6  1
 7  1
 8  0
 9  1
10  1
;
```

Findings

As we know, the goal of our project was to determine the most efficient route for participants to maximize the amount of charity that can be generated by visiting different bars with minimum distance travelled. From our model and analysis, we find out that 4-5-6-7-9-10-4 is the most optimal route considering our objective function and constraints with which we can generate a profit of $4042.5. In our computation, we have taken the conversion factor, α to be 0.5 since distance travelled cannot be completed neglected. α can vary from 0 to a higher value but as we start increasing it, maximum benefit would start decreasing. Hence, to keep a balance between cost and distance, α is considered 0.5. Participants following this route can generate slightly more or less than the maximum charity from bar crawling with given constraints.

Conclusion

In this project, we have tried optimizing the bar hopping problem which is basically like travelling salesman problem with profits. We have considered a small set of bars in Cincinnati, plotted their distance and benefits associated with them. Using Gurobi-AMPL model, we have then analyzed what would be an optimal solution to this problem given a bar hopping event is organized in this area output of which has been defined in the findings.

In a similar way, we can consider a bigger version of this problem and find optimal objective solution for that. The only challenge that we would be facing would be the increase in the subtours that will be generated when the value of nodes will increase but that can be encountered using Miller-Tucker-Zemlin formulation to eliminate subtours as we have used in our model at a smaller level.

The pub hopping events for charity are getting famous day by day, hence this model can prove to be effective in case we want to maximize the profits earned, keeping in mind the budget and time constraints that come along with such events.

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