Public Transportation Modelling: Planning Bus Lines Routes

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Abstract

Population growth and urbanization increase drastically the issues in urban mobility. Urban planners and traffic engineers need a tool to assess and find a set of optimum solutions for public transportation route. Implementing concepts of hydrodynamics to model the traffic flow in the city of Porto Alegre, Brazil in a diverse planner, multiple routes are found. The planner contains a Top -*k* algorithm. To choose the optimum path, is expected that a bus line must reach certain bus stops and using the most congested streets. Additionally, is prospected that the presence of the bus in high demanded streets, might decrease density in the route.

Introduction

According to the UN(2008), the world's population is expected to reach over 9 billion people until the end of this century. Additionally, 68% of total population is projected to live in urban areas. Therefore, the cities must adapt to this reality.

Urban mobility is among the areas that require urgent improvement. Besides to provide the citizens with life quality, but also to improve the efficiency of the city.

The study case is the city of Porto Alegre, Brazil. According to the statistics provided by the State Government (2014), Porto Alegre has 1 vehicle for each 1,8 inhabitant. Moreover the lack of efficient and sufficient public transportation contributes for massive congestion during rush hours in the city.

Awareness of multiple diverse solutions available for the problem is convenient to highlight solutions that might not be considered (Coman and Munoz-Avila 2011). Diverse Planning provides a set of adequate paths. To generate the set of plans, the planner can address a qualitative metric, or quantitative. Quantitative metric, that is domain independent, considers any two plan elements are equally distant from one another. Qualitative is based on interpretation using domain knowledge, and it is possible to vary the set of features along which one would like to see diversity, for example, in a travel domain, variation of ticket cost, but not the means of transportation (Coman and Munoz-Avila 2011). Thus, for the study case, using the number of vehicles on each street as the cost of plans, it identifies as a quality metric for the project.

In order for the planner to provide the set of paths, is necessary to compare each plan based on the quality metric. Once the desired diversity between plans is obtained, is not necessary to filter the results afterwards (Srivastava et al. 2007).

This paper proposes a method of finding the optimum path of a bus line that contemplates chosen bus stops. Furthermore, this tool provides a way to simulate and assess the impacts of the implementation of a new bus route in a city. Once there are buses in high demanded areas of a city with dense traffic, is more likely that the car volume decreases dissolving bottlenecks and improving the flow in the area.

Technical Approach

The definition of Diverse Planning solution, according to Katz and Sohrabi (2019) is: Let Π be a planning task and P be the set of all plans for Π. Given a natural number k, P $\subseteq$ P is a k-diverse planning solution if $|P|$ = k or P = P if $|P| < k$.

In order to formalize the search planning, it is required to have information about the network and traffic flow. To model the behaviour of traffic in Porto Alegre, it is considered a macroscopic traffic simulation based on hydrodynamics flow relation.

The Lighthill Whitham Richards (LWR) model for macroscopic traffic simulation considers the number of vehicles passerby per street and length of the network. These data are necessary to solve the Continuity Equation (Equation 1). This equation describes the temporal evolution. of the density as a function of flow gradients (Treiber and Kesting 2013)

$$Q(x,t) = \rho(x,t) * V(x,t) \tag{1}$$

Where Q is the flow in position x and time t, ρ is the traffic density is the number of vehicles per unit of length,in position x and time t, and V is the local velocity in position x and time t.

The road network is modeled as a graph, including nodes and links. Every intersection of streets on every corner is a node, while the streets between them are links.

Data such as street length is obtained from the links in the graph network that is available in the open source platform *Open Street Map*. Nevertheless, the number of vehicles that passes each street is not always accessible, still, some cities provide this information openly.

Each bus stop that needs to be reached in the considered routes. While most route planners consider the cheapest path, in this case, is more convenient to consider the more expensive. If the quality metric is the summed cost of the plan, it represents the path that is more congested and consequently, the route that requires a bus line the most.

Implementation

In order to generate the k best plans, the Forbid-Iterative (FI) planner was used under Fast-Downward. FI is an Automated PDDL based planner that includes planners for top-k, top-quality, and diverse computational tasks and was developed by Michael Katz, Shirin Sohrabi, and Octavian Udrea (2019). The planner is based on the idea of obtaining multiple solutions by iteratively reformulating planning tasks to restrict the set of valid plans, forbidding previously found ones.

Accoring to Katz, Shirin and Udrea (2018),the top-kplanning approach proposed reformulates a planning task of a solvable top-kplan-ning instance exactly k times. It is a very resourceful tool once it proposes more alternatives, giving the programmer, option to asset and choose.

To validate the planner, we executed in a limited area from the city of Porto Alegre as Figure 1 shows to location and in Figure 2, the simplified grid of this area. Up to the date of this paper, the necessary data is still incomplete. For this reason, we estimated the traffic flow on the remaining streets by half of the number of vehicles per hour of the nearest avenue.

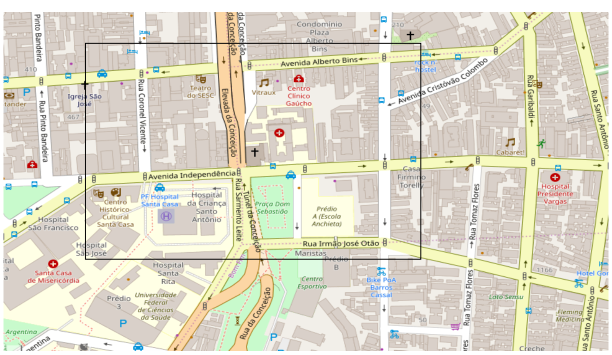

Figure 1: Study Case Area

The traffic flow data given by the city hall is from approximately from eight to twenty thousand vehicles per hour, according to Table 1. It was considered the inverse of the number, so the metric to minimize costs would give preference to the more congested street. Another consideration in the cost is the exponential of 10^6 to reach more manageable values.

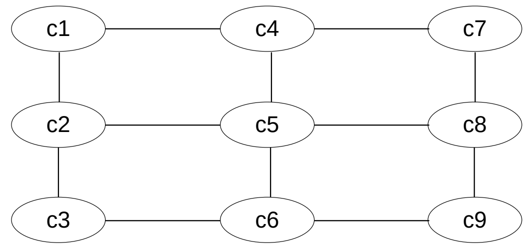

Figure 2: Simplified Network Grid

Locations	*Q(vehicles/hour)*	10^6
c1-c2	8.3333,3	120
c1-c4	8.3333,3	120
c2-c5	16.667,7	60
c2-c3	8.3333,3	120
c3-c6	8.3333,3	120
c4-c5	8.3333,3	120
c5-c6	8.3333,3	120
c5-c8	20.000	50
c6-c9	10.000	100
c7-c8	10.000	100
c8-c9	10.000	100

Since is a simplified version of the problem, the number of generated plans chosen is 3. The generated plans in represented by Figure 1, Figure 2 and Figure 3, represent 3 different paths that the FI planner found from the cheapest solution to the more expensive. We chose 3 plans intentionally in order to prove that no other plan fits this problem, forcing the planner to reach its maximum result capacity.

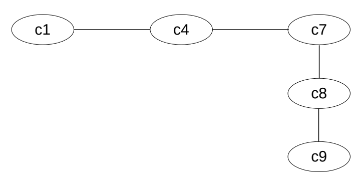

Figure 3: Plan 1

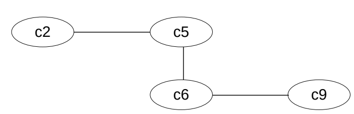

Figure 4: Plan 2

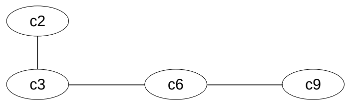

Figure 5: Plan 3

With this set of plans, a traffic engineer can choose one, that not necessarily is the one with the minimal cost. One of the proposals of this study, was to contemplate a set of required bus stops and as is observed, it is fulfilled by the second plan. Besides the bus stops, another reason for choosing a different plan can be avoid or benefit specific points, as hospitals, shopping malls or Universities.

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Related Work

Among various methods concerning traffic simulation, the macroscopic flow model described by Treiber and Thiemann (2013), assumes the traffic flow is similar to compressible fluid flow, called Lighthill Whitham Richards (LWR) model. Following the LWR model, Chu, Saigal and Saitou (2018) proposed a study to prevent in real-time traffic status using probe data. Moreover, studies that make use of automated planning tools to enable traffic to be managed using macroscopic simulation model modelling traffic as flow (McCluskey, Vallati, and Franco 2017). Voss, Moll and Kavraki (2015) proposed an algorithm that plans the route of a vehicle in a busy city,that the change of traffic does not change the set of valid paths, but the cost of the paths using diverse planning. The algorithm search a collection of required number of paths that satisfy the same goals considering obstacles.

Conclusion

The LWR model is very a approximated to real world traffic behaviour abstraction. With the implementation of the traffic density in the model, it is highly likely to simulate the traffic in Porto Alegre successfully.

The FI planner generated successfully the required number of plans. As expected, the optimum route considering the criteria of being the most demanded one is the one passing through the avenue.

There are still more to accomplish. With more complete data concerning adjacent streets and automatic importation of the map as a graph provide true representation of the city network condition. Besides, implementing in the domain a ”visited” precondition and effect regarding the required bus stops is also an forward improvement in the model.

Considering the model, is expected to generate a plan containing an optimum path contemplating the required bus stops to the route passing for the most dense streets in traffic matter. Additionally with this knowledge, is possible to update the LWR model with the latter traffic density with the new bus line and assess the impact on the network.

Therefore the objective of this proposal is to create a tool that can generate a mobility solution for highly demanded areas. While the traffic flow model provides trustworthy information concerning the demand, the planner generates a bus route that can supply this demand. Consequently, bus lines attending routes that are more required, decreases the necessity of people driving cars in this same routes, decreasing the traffic volume.

References

Chu, K.-C.; Saigal, R.; and Saitou, K. 2018. Real-time traffic prediction and probing strategy for lagrangian traffic data. *IEEE Transactions on Intelligent Transportation Systems* 20(2):497–506.

Coman, A., and Munoz-Avila, H. 2011. Generating diverse plans using quantitative and qualitative plan distance metrics. In *Twenty-Fifth AAAI Conference on Artificial Intelligence*.

Katz, M., and Sohrabi, S. 2019. Reshaping diverse planning: Let there be light! *HSDIP 2019* 1.

Katz, M.; Sohrabi, S.; Udrea, O.; and Winterer, D. 2018. A novel iterative approach to top-k planning.

Katz, M.; Sohrabi, S.; and Udrea, O. 2019. ForbidIterative planners for top-k, top-quality, and diverse planning problems.

McCluskey, T. L.; Vallati, M.; and Franco, S. 2017. Automated planning for urban traffic management. In *IJCAI*, 5238–5240.

Srivastava, B.; Nguyen, T. A.; Gerevini, A.; Kambhampati, S.; Do, M. B.; and Serina, I. 2007. Domain independent approaches for finding diverse plans. In *IJCAI*, 2016–2022.

Treiber, M., and Kesting, A. 2013. Traffic flow dynamics. *Traffic Flow Dynamics: Data, Models and Simulation, Springer-Verlag Berlin Heidelberg*.

Voss, C.; Moll, M.; and Kavraki, L. E. 2015. A heuristic approach to finding diverse short paths. In *2015 IEEE International Conference on Robotics and Automation (ICRA)*, 4173–4179. IEEE.