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. 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 proposal is to create 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.

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.

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 ⊆ 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, Porto Alegre provides this information publicly.

Each bus stop that needs to be reached in every plan of bus route has to be considered. While most route planners consider the cheapest path, in this case, is more convenient to consider the more expensive. Modifying the A* search algorithm to select the most expensive path is sufficient to adapt the search method in the problem. 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.

Diverse Planning finds very similar plans. Paths that share multiple edges are redundant and paths that do not reach the required bus stops are irrelevant. Considering the bus stops as landmarks is a valid strategy and aids to eliminate the redundancy and irrelevant path possible issues.

Project Management

The project will be developed in 4 steps, as following:

- **Week 17/10-24/10:** Definition the planning and make eventual corrections, test planners such as Dino,DLAMA and Fast Downward.Implementation of the traffic flow model to read the density data and prepare data for use;
- **Week 24/10-31/11:** Implementation of the proposed study in the planner;
- **Week 31/11-07/11:** Validation of the planner and implementation of other situations;
- **Week 01/11-08/11:** Write paper and corrections;

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.

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.

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