Measuring the MFD of Zurich – Identifying and evaluating strategies for efficient fixed monitoring resources

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1 Introduction

In this paper we develop and evaluate different advanced strategies for placement of fixed monitoring resources in the city of Zurich to measure current traffic conditions. The goal is to facilitate the introduction of a real-time traffic control scheme based on the Macroscopic Fundamental Diagram (MFD).

Here we focus on the appropriate number and selection of links to monitor in order to measure the current traffic state in an efficient way. That can be done by minimizing the number of links needed to obtain a certain accuracy, or maximizing the accuracy with a fixed amount of links. For this purpose we find blind strategies, i.e. strategies which do not need much traffic information a priori and combine them to find more accurate strategies. Furthermore, different ways to measure the error of estimation are developed and used to evaluate the strategies.

2 Background

Geroliminis and Daganzo (2008) showed that MFDs exist in urban areas. They describe the relation between space-mean flow, density and speed in those areas. It is usually infeasible to obtain the true MFD since it would require full information of the network (i.e. monitoring every link of the network). However the true MFD can be approximated by using detector and/or vehicle data (Geroliminis and Daganzo, 2008). To get the most accurate result, every single street of a city could be monitored, but this would be very costly.

To reduce this cost, Ortigosa et al. (2013) explored different strategies to approximate the MFD of Zurich by using only a fraction of all streets. The following blind strategies were analyzed:

(i) **Random:** Links were chosen completely at random.

(ii) **Distance to the center:** Links closer to the center were given a higher probability to be selected.

(iii) **Street hierarchy:** Bigger links (i.e. more lanes) were given a higher probability to be selected.

(iv) **Traffic signal:** Only links with a traffic signal were considered for selection.

To evaluate the strategies, data was created with a VISSIM microsimulation model achieving full information of the network. On the basis of this information, a “complete MFD” was obtained for reference to evaluate the accuracy of the different strategies.

The four blind strategies performed quite similar to each other: they all needed a high number of monitored links to obtain good results. A lower bound for the error was found with a Tabu Search optimization algorithm (Glover and Laguna, 1998). The results showed a significantly lower error than the blind strategies. Thus, there is a high potential for improvement and development of more advanced strategies.

3 Strategy Development

We expand the work of Ortigosa et al. (2013) by introducing more elaborated blind strategies and then combining all strategies to more (cost-) efficient advanced strategies.

Some of these strategies require information about traffic flows (e.g. connectivity, flow interception). We collect this information by using graph theory and a shortest path algorithm to allocate flows (Dijkstra). Evidently, this procedure is approximate, but we believe that it can provide the planner useful information to discriminate links. We consider the following strategies:

(a) **Interception of flows:** We select links which intercept a high variety of flows as described in Yang and Zhou (1998).

(b) **Connectivity:** We select links according to their importance in the network, i.e. critical links in terms of connectivity will get a higher probability to be chosen.

(c) **Worst intersections:** Links are selected among the ones adjacent to the intersections with the highest delay as in Ortigosa et al. (2013).

(d) **Spread:** Links will be chosen in a way that they form a uniformly spaced network.

In addition to these more elaborated blind strategies, we also added the following two simple blind strategies that might have an influence on traffic flows:

(e) **Parking:** The selection among links with a certain parking scheme.

(f) **Public transport:** The selection among links with certain level of public transport activities.

In a second step we combine the above strategies to create more advanced strategies. We define $D_s(n)$ as a subset of links with size n which were chosen from the whole set of links by a strategy s. One way we use to obtain a new more advanced strategy is selecting fractions of $D_{new}(n)$ by different basic strategies. For example choosing 10 links completely at random and 20 links with the distance to the center strategy to gain a set of 30 links for the estimation of the MFD:

$$D_{new}(30) = D_{(i)}(10) \cup D_{(ii)}(20)$$

Another way to create an advanced strategy is using links which are selected by two basic strategies simultaneously. For example, take all links which have a traffic signal downstream and are spread on a uniform network:

$$D_{new}(n) = D_{(iv)}(100) \cap D_{(d)}(50)$$

This way of creating strategies does not require additional knowledge. It only requires information from the basic strategies, which use data that is usually known to traffic planners.

4 Strategy Evaluation

For the evaluation of strategies, we use the VISSIM microsimulation data from Ortigosa et al. (2013) for the inner city of Zurich between 5-6 pm on a weekday. To cover different demands, the simulation was run with multiples of the original demand. A limitation of the model is the fixed route choice because traffic might not be as well spread over the streets as it would be in real life. In total the model was run with 25 different demands, 5 random seeds each, and data was collected every 5 min for the 461 links (1500 different traffic states to measure the MFD).

The goal of measuring the current traffic state with the MFD is to assess how far the system is from congestion. For that Ortigosa et al. (2013) introduced the concept of measuring the ratio between the density at a time t to the critical density k_{cr} of the system. To evaluate each strategy, the average difference between the ratios of the complete MFD and the ratios of the measured MFD is computed. We use this tool again to evaluate the advanced strategies.

Complementary to this we also evaluate the variance of the estimation to check the reliability of each strategy.

The goal is to provide various advanced strategies to place loop links for measuring the MFD as well as the current traffic state in a (cost-)efficient way. Each strategy will be evaluated according to its accuracy and variance of estimation. This should provide decision makers the necessary information to implement a strategy according to their needs.

Although, the strategies are tested based on data from the city of Zurich, they should have the potential to be implemented in other (comparable) cities as well.

5 References

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