Automatic dynamic traffic flow model of highway networks based on open data

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1. Problem and research questions

Traffic models have been developed for many reasons. In their most basic form they are used to clean and filter raw data gathered in the field [1]. More advanced methods construct indicators about realized traffic conditions and make predictions about their evolution [2]. The most advanced techniques are able to make estimates about future scenarios [3]. The ever increasing availability of data about all aspects of transportation (floating car data, camera observations (CCTV, ANPR), mobile phone tracking etc.) gives us the impression that some of these models are becoming obsolete. We argue that this myopic view does not only limit us in the scope of our analyses, but it also leads to suboptimal decisions right now. Obviously no observations are available about the effect of policies far into the future and convincing strategic models are required to extrapolate behind the horizon of currently existing or previously tested scenarios. But also for operational decisions, a purely data-driven approach might undermine the efficacy of an application. Direct feedback in observations can lead to non-optimal operations like for example at signal controlled intersections [4].

It is therefore important to integrate model developments for transport planning and operations with the ever increasing availability of data. The combined methodology should be convincing and trustworthy, easy-to-use, able to reproduce observed data and predict the future with a high accuracy. In this paper we will show that within a reasonable scope such integration between models and data is feasible.

This article presents an open-source code for the automatic generation of a dynamic traffic flow model of highway networks based on open data of the Flemish Highway system. It is developed in Matlab by the L-Mob Research Center at the KULeuven and distributed as a free & open source project on GitHub[1]. The application allows users to visualize traffic data and to automatically generate simple traffic models for any corridor along the highways of Flanders (a region in Belgium). It is connected to the open data platform of Flanders and uses the live traffic feed of data collected by double loop detectors along the highways. The dynamic traffic flow models can be used to analyze the impact of different traffic management scenarios such as the opening of a peak hour lane or the introduction of variable speed limits.

2. Methodology, research strategy

The road network is created by combining the digital topological reference map of Flanders (GRB) with extracts from https://www.openstreetmap.org to fill in missing fields and features.

[1] https://github.com/HimpeWillem/OpenTrafficCenter

For traffic applications, the most important characteristics of the resulting graph is its connectivity and main properties related to traffic throughput on all the road segments (speed limit, number of lanes, and direction of travel…). In total 11183 edges are described summing to 2980km of road, see also figure 1. In a final step all of the double loop detector stations are mapped to corresponding road segments such that the data can be used to infer traffic conditions on the entire network. For computation simplicity, in the current version only corridors without route choice (defined by the shortest path between user provided start- and end-points) are modeled.

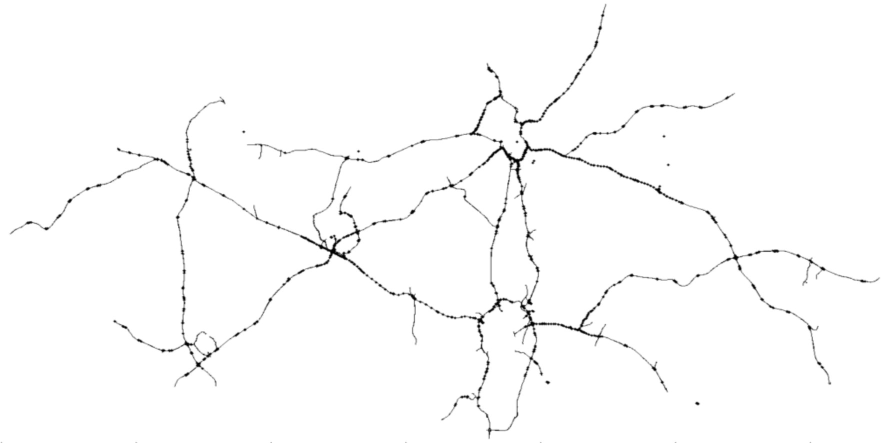

figure 1: Overview of the highway network in Flanders (Belgium).

The application is built in four phases

- Select and visualize data along a selected corridor
- Automatically setup a dynamic traffic model for that corridor
- Assist the user to calibrate some basic parameters of this model (e.g. bottleneck capacity)
- Run and analyze reference and alternative scenarios

The real time traffic data coming from the double loops is comprised of volume counts and aggregated speeds for 5 different vehicle classes. It is updated every minute so for the analysis of congestion patterns over different days and time periods the data is stored, repackaged and made available on http://www.itscrealab.be as a direct download or through a PostgreSQL interface. Inspecting the data like in figure 2 allows verifying fundamental relations of traffic states and capacity of bottlenecks.

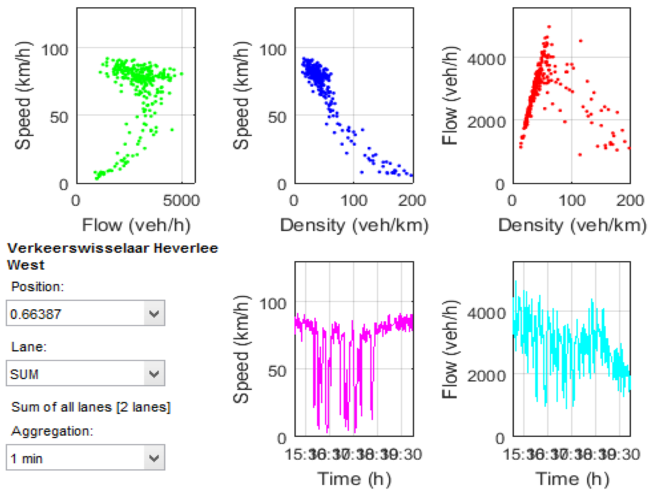

figure 2: Overview of the highway network in Flanders (Belgium).

The collected observations along a corridor are smoothed and interpolated in a rectangular space time grid to be visually inspected (figure 3). This is done using a filtering technique that takes into account the spatio-temporal relations in traffic [1]. For most analyses it is recommendable that the head of the queue be present within the corridor such that the workings of the bottleneck can be observed.

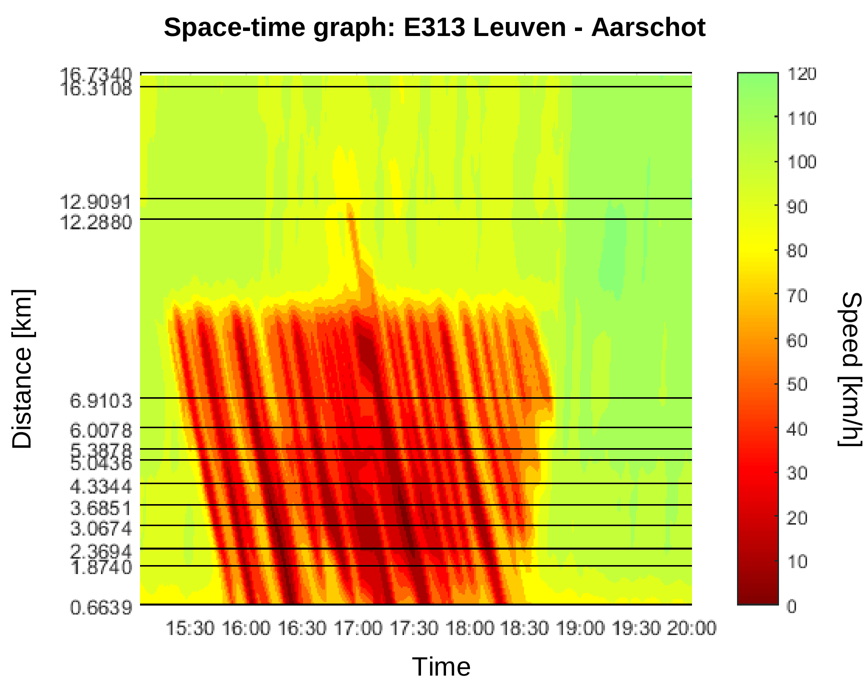

figure 3: Visual of the observed congestion pattern on the E313 corridor near Leuven running east. The horizontal lines are detector stations.

The main traffic model is composed of a dynamic network loading (DNL) algorithm. This algorithm simulates the evolution of the network's congestion state through time. It requires two time dependent inputs: the demand in a network that is to say the number of vehicles wanting to enter the network at any given time, and where the vehicles flow (specified by turning rates at each diverge). This research study uses a specific class of DNL methods known as Link Transmission Models (LTM). These algorithms offer a macroscopic approach based on Newell's simplified theory of kinetic waves [5]. More specifically, the LTM used throughout this study has been developed by [6].

The on-ramp demand and split rates are derived directly from count data. Wherever a detector is missing, data is filled in by propagating flows originating from up or downstream counts using conservation of vehicles within links and over nodes. The addition fundamental parameters such as capacities of road segments and jam densities are assumed to be homogeneous and equal to standard values [7] per lane. A further analysis of these values for different road conditions and weather types is left for further research.

3. Major findings

In this section the model output of one specific corridor is presented. The congestion pattern on the E313 highway near Leuven is modelled. Comparing figure 4 with the observed congestion pattern in the previous section illustrates how the model can indeed reproduce bottleneck activation and congestion propagation as observed in the data.

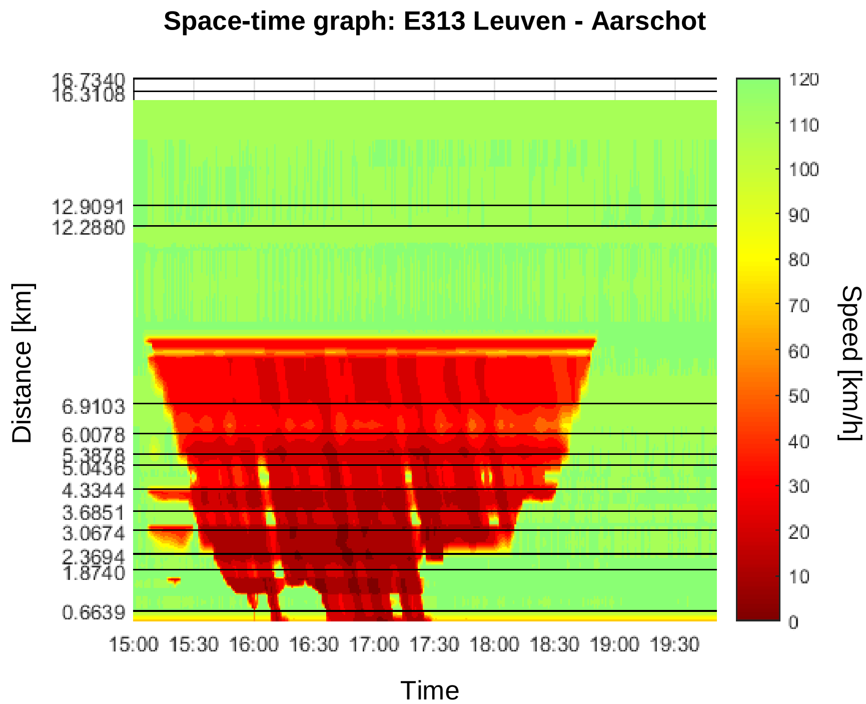

figure 4: Visual of the modelled congestion pattern on the E313 corridor near Leuven running east. The horizontal lines are detector stations.

This can also be seen by comparing the model speed and flow on segments with a detector station: in figure 5, model and data are compared for the first detector upstream of the bottleneck location.

4. Takeaway

The presented example shows a reasonable fit to the data with standard model parameters. An even better fit is possible by calibrating the capacity of the bottleneck or the standard values (like jam density) of different highway sections.

The practical priority rules at merges that are used by the model in case of congestion spillback are rather simplistic and based on entry capacities just as described by the general node model [8]. On highways, traffic often clears the right lane at on-ramps such that this capacity-based priority distribution isn't always accurate. It is then recommendable to calibrate appropriate on-ramp capacities accounting for this.

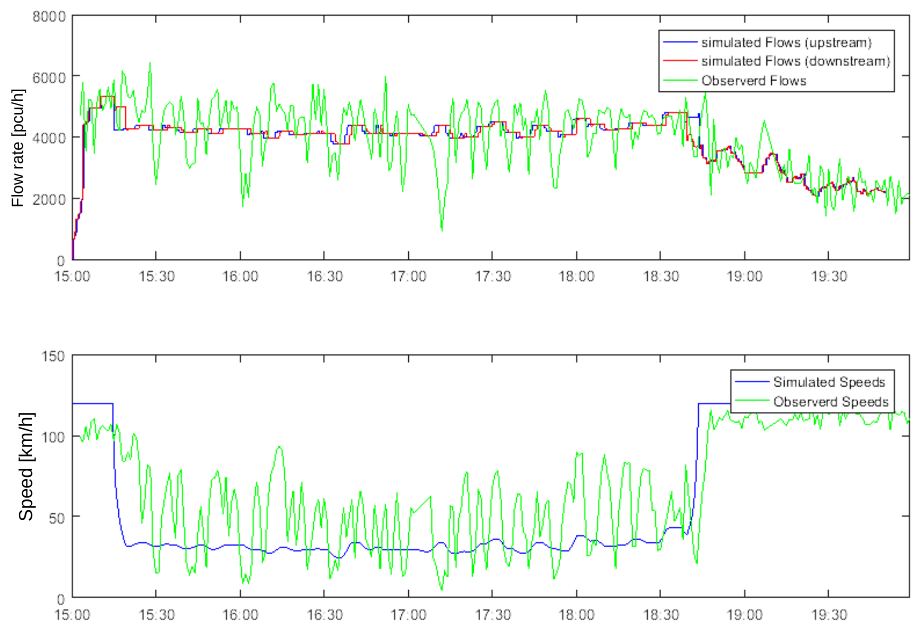

figure 5: Direct comparison of model output and observations of the first detector upstream of the bottleneck location. The top graph shows the flow rate (pcu/h). The bottom graph shows aggregated speeds (km/h).

The model can now be used to evaluate scenarios like for instance the opening of peak hour lanes downstream of the current bottleneck (under *ceteris paribus* assumptions, i.e. only propagation changes, and no other effects like re-routing, re-timing or elastic demand are considered) . In the illustrated case, such measures would reduce congestion substantially.

The performance of the corridor can be evaluated and compared for different days to show variability in bottleneck throughput. Note that the capacity at weaving sections can be dependent on the amount of the competing flows which is often variable over the peak period making the capacity of such sections variable over time (the current implementation is limited to a fixed capacity value over the simulation interval). Also, demand variations can also be observed for different days. This allows us to compute elasticity or responsiveness. As such these tools are useful for gaining insights in the behavioral response in case of accidents or at road works.

Finally, our results enable large-scale dynamic traffic assignment models that will replace stationary predecessors generally used for strategic planning of entire regions. The tools have already been used to quickly scan parameter space of the dynamic model for Antwerp and Brussels.

5. Keywords

dynamic traffic model, real time open data, strategic analysis, traffic control center

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