

DATA FUSION TECHNIQUES FOR TRAFFIC STATE ESTIMATION – DINO WITHIN DMOTION

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ABSTRACT: This paper presents the data fusion techniques in the R&D project - Dmotion, in which the system of real-time traffic state estimation (DINO) has been further developed for the conurbation of Düsseldorf, Germany. Moreover, the required traffic data and data sources for data fusion are also described in this paper. It is expected that the traffic state in Düsseldorf can be monitored more accurately with the use of the proposed data fusion techniques. The respective research is still under progress and the results will be available within a few months.

INTRODUCTION

Dmotion is a German research project, which belongs to the research program of Traffic Management 2010 (vm2010) that is funded by the German Ministry of Economy and Technology (BMW). The aim of Dmotion is to develop and implement an integrated traffic management system for the conurbation of Düsseldorf (see Figure 1). One of the objectives of Dmotion is thus to generate a consistent, comprehensive and up-to-date report on traffic conditions for the Greater Düsseldorf. This serves as the decision basis for a strategy management that couples the urban traffic center with the motorway control center and private suppliers of navigation and routing services. As the covering with sensors is relatively poor in the urban area, it is a necessity to use as many traffic data sources as possible in the process and to incorporate data fusion and data completion techniques. To this end the real-time traffic state estimation tool DINO (Dynamic Net Monitor) is applied and extended in the research project.



Figure 1: Network of the conurbation of Düsseldorf

THE PREVIOUS PROTOTYP: DINO WITHIN MOBINET

DINO was originally developed by Filippo Logi and Marc Ullrich in the R&D project Mobinet in 2001 and is designed for comprehensively estimating the traffic state in Munich (1). The execution process of DINO involves two phases. Firstly, DINO starts calculating an estimated traffic state with the quasi-dynamic assignment algorithm 3DAS developed by de Romph (2). Secondly, DINO calibrates the given Origin-Destination-Matrix (OD-Matrix – a representation of the number of tours between all pairs of zones within the network) by applying a modified information minimization algorithm, originally introduced by van Zuylen (3).

This procedure will continue iteratively with the assignment of the latest calibrated OD-Matrix either until there is no significant change between the calibrated OD-Matrix in the last two iterations or until the allowed computing time is reached. Finally, DINO ends with the outcome of traffic information on all traffic links in the investigated network with the application of the 3DAS-Algorithm.

CURRENT RESEARCH AT DATA FUSION

Caused by the poor covering of the conurbation with traditional detectors (induction loop, infrared or video sensors) which count the amount of traffic in terms of flow and the unbalanced distribution of measurement points functional enhancements in DINO are needed in order to effectively apply DINO in Düsseldorf. The following sections explain the types and the sources of the data additionally used in Düsseldorf and finally the used data fusion techniques.

ADDITIONAL DATA AND DATA SOURCES

To apply data fusion techniques in traffic state estimation effectively and efficiently, many different sorts of data for generating real-time traffic data are required. Three kinds need to be distinguished here: In the first place the raw field data from static infrastructure points: They involve the data collected from sensors and loops near traffic lights and video or infrared sensors on road sections in the free flow, both inner-urban and on the motorways surrounding the city. In the second place the aggregated data from traffic models that examine a limited part of the road network are used. Among the latter is the so-called spill back estimator from the German company TransVer GmbH (4) that estimates the queue length at signalized intersections with high accuracy. Additionally a new traffic model is being developed within Dmotion that calculates the spillback at the transition points from the motorways to the city road network based on aggregated counting data and green times. In the third place probe data from vehicles is available to the data fusion process. The vitally source of information of this kind is the taxi fleet in Düsseldorf with 1300 vehicles. The taxis issue trip information that is analyzed in the so-called Floating Car Evaluator (FCE) from the Austrian research institute Arsenal Research (5). The results of the calculation are current and historic travel times for every link in the road network. Additionally floating car data from other sources is utilized: Probe data from private fleets from the company PTV AG and from BMW AG issue travel times and incident warnings. The registration and deregistration of public transport vehicles at prioritized junctions is used in a separate traffic model to calculate traffic state information for links where public transport and individual traffic share the same space.

Sensors and traffic models for sensor or floating car data export various results: Traffic volume, travel times, queue lengths, incidents and level-of-service information. This data is qualitatively distinct and can be used at different points in the data fusion process. Therefore the concept of quality is introduced to cope with the different models. This concept forces every traffic model to judge the current quality of its output values on a basis from 0 (pure guess) to 1 (absolute certainty). Only with these quality values the heterogeneous traffic models can be fused to a consistent view of the current traffic state in the whole road network. This quality index needs to be established and adjusted for every traffic model based on experience, simulation studies and field trials.

DATA FUSION TECHNIQUES

Based on the above mentioned additional data several data fusion techniques are studied, implemented and tested in this project. In this paper one data fusion technique for the 3DAS-Algorithm is described. The 3DAS-Algorithm is the assignment algorithm used in the first phase of the execution process (see Figure 2). In the second phase of the execution process another data fusion method is introduced for calibrating the OD-Matrix additionally by travel times and finally one data fusion method is used for the overall program termination.

3DAS-Algorithm

Within the 1st phase of DINO an assignment of the recalculated Origin-Destination-Matrix to the road links of the strategic road network of Düsseldorf is calculated. It uses the 3DAS-algorithm which was developed in 1994 by de Romph at the Delft University of Technology in the Netherlands.

In this algorithm traffic lights are represented by green time ratios on road links. Almost all signal timing data are transmitted between the traffic management system and the traffic signals in real time in Düsseldorf by using the OCIT-Interface. So it is possible to make use of the real-time green time ratios instead of fixed values from a database. In regard to the traffic signals without the real-time data transmission function the required green time ratios will be retrieved from the respective current signal plans and by sending this information to the traffic management system. Using this information and a database of all possible signal plans real-time information about the green time ratios is generated.

Modified Information Minimization

Due to the described motivation for data fusion also travel times are used for the calibration of the OD-Matrix within Dmotion. Both the modified and the original information minimization algorithm are based on flow values. Therefore a conversion from travel time to flow is needed.

Within Dmotion an indirect calculation of correction factors is used. Instead of continuous functions a travel time based classification was specified. Depending on the travel time at the road a category and a traffic flow representation for this category is chosen. Therefore for every road a typical travel time t_{typ} has to be determined. This can be done using the length of the road link and the cycle time of the signal controller. Within Dmotion three categories are used:

- $t < t_{typ} - x$
- $t \in [t_{typ} - x, t_{typ} + x]$
- $t > t_{typ} + x$

The parameter x is specified with respect to the above-mentioned quality of the measured travel time t . For exact measurements a small and for inexact measurements a large tolerance are used.

For every road and category a flow value representing the saturation flow based on the current green time is predefined. If this flow value of the chosen category q differs too much from the

The decision for or against an earlier termination is based on an evaluation of the result of the current assignment. Therefore a punishment value F is calculated for every assignment result. This term describes the overall difference of the estimated traffic state in comparison to the measured one. F is calculated as a weighted sum of local difference of DINO-calculated and committed values $|\hat{x}_i - x_i|$ for every link i . On the one hand the weight of a local discrepancy depends on the quality γ_i of the committed data. For exact data higher weights are used than for inexact data. On the other hand the weight is affected by the kind j (c_j) of the given data. Because of the very high influence of any great local difference it is softened by the exponent y_j .

$$F = \sum_j c_j \sum_i \delta_{ij} \gamma_i |\hat{x}_i - x_i|^{y_j} \quad \text{with } \delta_{ij} = \begin{cases} 1 & \text{iff } x_i \text{ belongs to data kind } j \\ 0 & \text{otherwise} \end{cases}$$

CONCLUSION

The effectiveness of the enhanced DINO in modelling traffic conditions with data fusion techniques is a fundamental prerequisite for the success of the Dmotion project and of transportation management and information strategies in the conurbation of Düsseldorf. Previous experience in the development of the traffic state estimator DINO demonstrated the validity of the approach, but in comparison to Munich it highlighted the necessity of data fusion in Düsseldorf. This paper describes several data fusion techniques for traffic state estimation using available additional data.

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