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Leveraging rapid simulation and analysis of large urban road systems on HPC☆

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ABSTRACT

The scalable implementation of a microscopic simulation, presented in our previous work, opens new areas of applications for traffic simulation, namely short term traffic forecasting. It can be used for real-time prediction of local, exceptional situations. Moreover it can be used as a hypothesis verification tool for evaluating different strategies of traffic control. In order to realize such simulations in a very short time (what is crucial here) a sufficient computing power is necessary what can be achieved using dedicated HPC hardware. In this paper we present methods for rapid analysis of simulation results for large urban road systems, where a local, exceptional situation can remain unnoticed. We propose new metrics for detecting and locating such situations. The detected situation can be handled automatically with the method based on the multi-variant planning approach.

1. Introduction and motivation

The domain of urban traffic modeling and optimization has been studied for decades now. Efficient transportation is one of the crucial foundations of modern societies and economy, which however still poses many unsolved problems related to efficiency, safety or ecology.

Over the years the researchers have proposed countless approaches to the problems, showing that many improvements in the domain are possible (Liu, 2007; Dumbaugh and Rae, 2009; Rossetti et al., 2011). Various methods have been applied in practice, making the traffic more fluent and safer. Nevertheless, urban road systems still experience significant efficiency issues caused by various exceptional situations, which are not handled properly even by the state-of-the-art urban traffic control (UTC) systems. This class of problems is currently one of the most important challenges of the domain, as stated in the recent survey on short term traffic forecasting (Vlahogianni et al., 2014).

The exceptional situations can include global conditions changes, like a weather breakdown, or local incidents, like accidents, large groups of pedestrians, movements of privileged cars or even Sunday drivers. Prediction and timely reaction for such cases is one of the open problems of the UTC systems.

Solving the issues of urban traffic requires models of the phenomenon, which are used for predicting changes and evaluating solutions. Traffic modeling is a mature domain, with a well-established classifications of methods. The most common classification distinguishes three levels of traffic modeling approaches i.e. macro-, meso- and microscopic models (van Wageningen-Kessels et al., 2015). The distinction between particular modeling types reflects the limits in the abilities of automatic model processing. General, meso- and macroscopic models can cover whole cities or even countries without going into details of particular roads or cars features.

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They can be used for forecasting the future states of the traffic very fast. They are useless, however, for predicting results of local, unexpected situations.

The microscopic models focus on representing individual cars, dynamics of their movements and details of single roads, lanes and junctions. The microscopic models can be really useful since recent results (Błaszczyk et al., 2015, 2017) show that even the driving style of individual drivers has significant influence on the overall efficiency. The problem however is that the high accuracy of the model results in really high computational complexity. To address the issue and to obtain road situation forecasting fast enough for on-line traffic management High-Performance Computing hardware can be applied, what has been shown in Turek (2018).

The acronym of HPC is used in this paper with different phrases following, e.g. HPC-grade, HPC-hardware, HPC-simulation. All of them are used in the context of (super) computing-cluster, i.e. distributed (super) computing units wired with (super) fast network for running appropriately constructed, (highly) scalable traffic modeling, forecasting and optimization software.

In the context of traffic micromodeling and reacting appropriately on (local) incidental, unexpected situations apart from the high performance computational environment the crucial issue is the question how to identify such situation(s) in the system.

Different metrics reflecting the situation on the roads can be found in the literature. The most obvious one include *travel time*, *waiting time* and *percentage of stopped cars*. More complex metrics integrate several values – the *delay* can be defined as the difference between the optimal and the actual travel time, the *flow* is calculated as the *density* multiplied by *average speed* (Balan and Luke, 2006). Other metrics consider less obvious factors, like *fairness* or *energy consumption*.

The problem however is that aforementioned metrics are mainly based on meso- or macroscopic models and aggregate data and values coming from coarse-grained parts of the modeled area like whole roads, districts or cities, etc. In the consequence, since they do not represent the details of the road system state, they are not able to reflect rapidly and precisely incidental situation happening in separated points of the modeled area.

In this paper we present the HPC-based simulation method applied for rapid analysis and detailed understanding changes in urban road system. We propose a method for automated short-term planning, which can properly handle incidental situations in separated points of the road system. We discuss also a toolset for processing simulation data and generating extended metrics and their changes over the time.

The overall concept of our idea implemented in a prototype system can be seen in Fig. 1. Here one can see that during the constant monitoring of the traffic in a city, some emergency arises (e.g. a traffic jam). The situation can be detected automatically using one of the state-of-the-art metrics or located manually by an expert. At this moment, leveraging a HPC-grade cluster available, a number of possible scenarios for the city is simulated, testing different solutions applied to the emerged problem. This approach allows finding out what is going to happen in the city after a specified period of time in several possible counteract variants (i.e. applying several possible solutions to the arisen problem). These outcomes are instantly handed over to the decision maker who chooses one of the scenarios (possibly the best one) and applies it in order to counteract the emergency. The monitoring continues and the system is ready to tackle another problem when it arises.

In proposed traffic management supporting system we integrated three elements for rapid analysis and understanding the future changes in the urban road system:

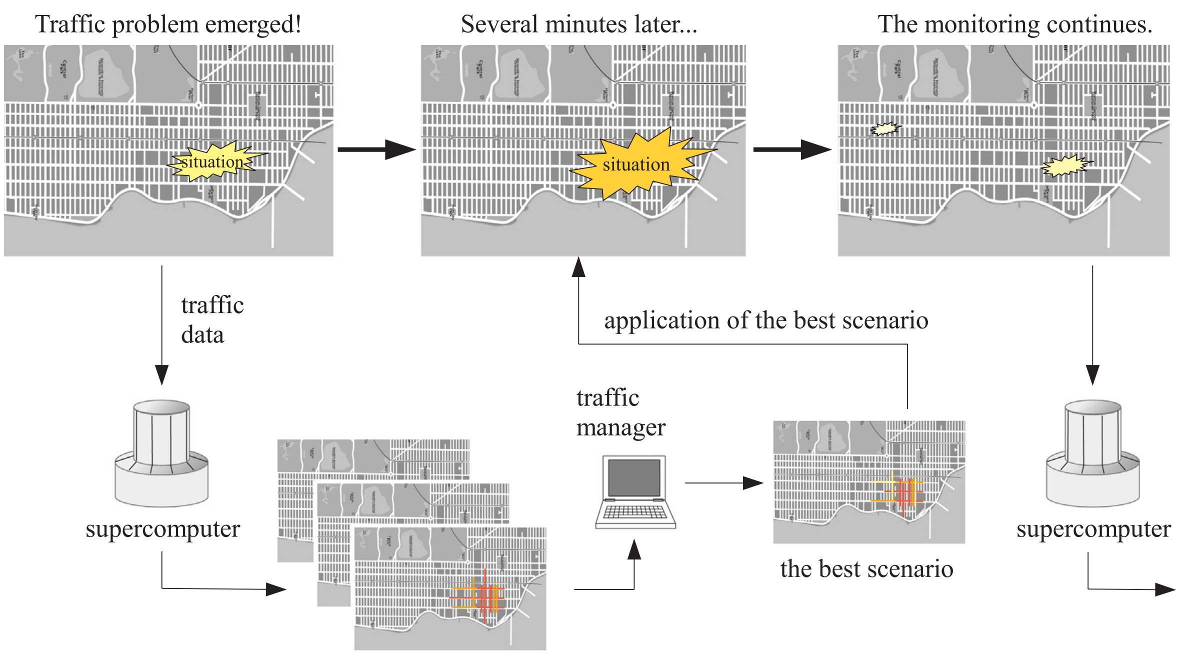

Fig. 1. A schematic view of the rapid traffic simulation and analysis system.