論文の内容の要旨

Abstract of Dissertation

Multi-Objective Assessment and Optimization of Highway Monitoring System

(高速道路モニタリングシステムの多目的評価と最適化に関する研究)

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To ensure the mobility of our cities, intelligent transport systems based traffic management became essential to operate existing highway networks in the most efficient way. Models estimate traffic conditions, predict traffic states in the short and long-term, and provide traveler information to keep the traffic flow as fluid as possible. The more intelligence those prediction and control systems have, the more they rely on feedback information from the monitoring system. If such information is unavailable or the systems are fed measurements from wrong locations, the advanced traffic management cannot perform to the expectations, and might even turn out to be counterproductive. Therefore, it is important to have a detection plan, which is designed to serve policies of the road authority, so that highway control systems can perform in an optimal and cost-efficient manner.

While research focuses on using available traffic data sources to improve traffic models and control systems, less work is devoted answering the question of how and where to collect traffic data. Common in previous studies is that they result in case specific, non-transferable optimizations for the single traffic management strategy. The real-world study developed a method, including GPS data collection and mathematical tools, to effectively determine preferable detector locations for the objective to minimize the travel time estimate error. However, no hint was given what effect the new

detector locations would have on incident detection, or how they could serve for additional purposes such as feeding ramp metering algorithms. The underlying problem is that these studies optimize the input for a specific algorithm, instead of actually identifying the information gained from the traffic detection.

The objective of this research is to analyze the detection efficiency and optimize the detector placements for multiple traffic management purposes. To achieve this, a multi-objective assessment and optimization scheme of highway monitoring system is necessary to be established. I present a systematic framework to evaluate traffic detection systems, by introducing the level of detection as value to allow for the comparison of multiple detector placement scenarios. By maximizing the level of detection with budget constraints, optimal detector locations can be determined for multiple traffic operation purposes. In contrast to existing studies, proposing new or alternative detector locations based on errors of travel time or traffic state estimators, this approach is solely based on detection technology, traffic conditions and network parameters, which allows the usage of the framework for highway operations, as well as planning purposes.

This research concludes four core aspects: traffic data supply, traffic data demand, multi-objective assessment model and detector placement optimization.

Traffic data supple represent the expected accuracy of measured data in the sensor vicinity according to the sensor technologies applied in monitoring system. As data collection is not only depends on sensor technologies but also traffic conditions and detector locations, data supply functions are defined to represent data availability and quality with a “valid range” of point detection information and variation of data accuracy. These functions quantitatively describe the relationship between working performance of a detector and its location. To determine the detection performance under different traffic conditions, traffic simulation with a dynamic traffic assignment (DTA) model is utilized to verify the data supply function. To give more clear vision of the collected information, detection knowledge maps are created based on the DTA simulation results.

Compared with data supply functions, data demand functions are independent from detector types and locations. Different types of data need be collected in essential spots and even a whole link to support traffic management measures or provide travel information to drivers. Data demand functions are determined based on requirements of various traffic applications for reliable incident detection, travel time estimation, traffic control and traveler information systems. The data demand function for a link is the maximum over all demands at a certain location. However, by introducing weights, based on policies of the road authority, it is possible to emphasize certain demands.

A multi-objective assessment model is developed to evaluate highway monitoring system with respect to detection accuracy (level of detection) and reliability (buffer detection index). By translating traffic operation goals into data demand functions, and detector capabilities, combined with their location, into data supply functions, level of detection is a ratio of data supply to data demand, which indicates how many percents of the data demand can be supplied by the sensors placed. It is an objective indicator of detection assessment for potential improvements of detector placements. The assessment model not only considers collected data accuracy, but also detection reliability introduced as buffer detection index. The buffer detection index represents variation of the detector performance that highway authorities have to consider in the traffic operation.

Monitoring system optimization is achieved by determining the optimal detector placements. A genetic algorism based methodology is developed to maximize the level of detection for every link of the network. To fill the gap between road link optimization and network-wide optimization, the network analysis is studied as well to identify the importance of each link.

Several case studies have been done for verification of demand-supply assessment framework. The studied areas includes and Route 4 of the Tokyo Metropolitan Expressway in Tokyo, Japan, the motorway A13, close to the City of Delft in the Netherlands, the Route 101 in San Francisco, USA. Finally I select C1 Route of the Tokyo Metropolitan expressway as an example to apply the approach for multiple traffic management purposes. All the data used for verification is real field data from the International Traffic Database (http://www.trafficdata.info).