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論 文 要 旨

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要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

Transportation systems have become an integral part of the modern society and our lives. Without exaggeration it could be said that almost all of our activities are related to these systems in some extend. People all over the World rely on transportation systems on the everyday basis when they commute to work or perform the leisure activities. These systems have indeed changed the way how we live and how our society is organized, therefore transportation systems have a great impact on the development of our civilization.

However, no matter how advanced modern transportation systems are, due to internal or external factors, these systems can fail and their behavior could become abnormal. And the failure in those systems could result in great social and economic losses. Therefore, understanding of the behavior of transportation systems not only under the normal conditions, but also under abnormal conditions is essential in order to maintain an efficient and stable operations of these systems.

Despite the necessity of understanding how transportation systems perform under various conditions, the actual analysis of their behavior is extremely challenging procedure. For instance, in our modern society automobiles play a significant role in transportation and one could hardly talk about urban transportation while avoiding talking about vehicle traffic. Meanwhile, the rapid increase in travel demand and growing motorization rate in urban areas all over the World making the analysis of traffic dynamics more and more complicated. This situation is becoming even more challenging, taking into account the existence and negative impact of unexpected disruptions, such as natural or manmade disasters. These disasters have a disruptive effect on traffic conditions and typically result in formation of unexpected or abnormal traffic patterns. As a result, normal operations could be severely degraded or even completely stopped. These situations have to be timely noticed and avoided as much as possible. And due to the complexity of these systems, there is no uniform approach capable to accurately and precisely accomplish this task.

This problem is indeed very difficult to solve, yet fortunately there is a bright side. The constantly growing amount of traffic data available nowadays make it possible for civil engineers to develop new and more efficient solutions based on the insights mined from this data. However, not only the amount of available information is increasing, but also its complexity. Therefore, the problem of appropriate data modeling is becoming critical in order to ensure appropriate representation of real-life phenomena.

Indeed, it has been highlighted in numerous studies that the traffic dynamics in large urban transportation networks, and as a result abnormal traffic patterns, typically exhibit complex spatiotemporal structure, therefore spatiotemporal correlations are an essential components of analysis and have to be handled and modeled appropriately. This appropriate modeling of complex spatiotemporal correlations of traffic dynamics is closely related to the mathematical objects used for traffic data representation. For instance, methods relying on matrix-based traffic data representation are not capable of handling dependencies along more than two modes of traffic data simultaneously. As a result, the dependencies, for example, only along one spatial and one temporal mode could be simultaneously taken into account. However, the real-life situations are usually more complicated and assume existence of dependencies along more than two modes. Regarding traffic dynamics, this could be spatial correlations, temporal correlations within a day, as well as day-to-day correlations inside particular urban region. In order to take into account all of them simultaneously, other mathematical objects than matrices have to be used.

In this dissertation the aforementioned problem of detection and description of anomalous traffic patterns is put forward. More precisely, the explanation of background and clarification of research objectives are provided in the first chapter of the dissertation. The second chapter is

devoted to the literature review on traffic modeling approaches in large transportation networks, traffic data collection techniques and methods for abnormal traffic patterns detection. Further, in order to address the aforementioned issue connected with the appropriate modeling of complex structure of traffic dynamics, in following chapter three the tensor-based traffic data representation is put forward. Tensors, being a generalization of such mathematical objects as scalars, vectors and matrices were recently introduced to transportation domain. Tensor-based methods operate with multi-way matrices in order to capture underlying complex structure of traffic dynamics. This key feature of tensors allow to model complex spatiotemporal nature of traffic data more accurately. Following this tensor-based representation further, in this study the novel approach based on tensor robust principal component analysis is proposed in order to detect anomalous traffic patterns and separate them from the expected ones. In contrast with conventional abnormalities discovery methods, proposed approach allow not only to detect abnormal traffic patterns, yet to conclude what actually caused them. Further, in order to validate proposed abnormal traffic patterns detection approach and examine its properties the simulation has been conducted in chapter four of this dissertation. In particular, in order to emulate overall behavioral characteristics of traffic dynamics in large urban transportation networks, continuum based model of traffic dynamics has been employed and extended. According to this conceptually different approach, the road network within urban area is assumed to be dense and viewed as a continuum in which travelers can travel in two-dimensional space. This transition allow to focus on the overall behavior of travelers at macroscopic level, rather than model and analyze each road link separately. Therefore, less amount of data is required for the model and the problem size could be reduced even in case of large and complex transportation networks, which become crucial for investigation the performance and properties of proposed tensor-based approach. In following chapter five, proposed abnormal traffic patterns detection approach has been applied to the real large-scale traffic data in order to mine abnormal traffic patterns. More precisely, probe vehicle data collected from the vehicles traveled in Tokyo area has been utilized. After necessary data aggregation, cleansing and preprocessing stages, probe vehicle data has been transformed into a tensor representation and analyzed with the help of proposed tensor-based approach. As a result, anomalous traffic patterns formed due to severe weather conditions have been successfully identified. Moreover, the performance of detection and properties of proposed approach has been examined in order to suggest the reasonable choice of parameters for traffic monitoring systems, which makes the study interesting not only from the point of view of theoretical developments, but also from the point of view of practical applications. The final chapter six of the dissertation is devoted to the conclusions, where key research findings are summarized and the future research directions are described.