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Title(English)	DEVELOPMENT OF REAL-TIME CRASH PREDICTION AND INTERVENTION MODEL FOR URBAN EXPRESSWAY WITH DYNAMIC BAYESIAN NETWORK AND DEEP REINFORCEMENT LEARNING
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種別(和文)	論文要旨
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博士課程）
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論 文 要 旨

THESIS SUMMARY

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

This thesis is about improving safety of urban expressways. In order to achieve this goal, a real-time crash prediction model (RTCPM) and intervention is proposed. The idea of real-time crash prediction to identify the hazardous traffic condition leading to crash in advance to take measures to avoid the crash. RTCPMs are highly dependent on high quality and high density traffic and crash data. These data are collected from the detectors or sensors installed on road networks. For this thesis, route 3 Shibuya (11.9 km) and route 4 Shinjuku (13.5 km) - two radial routes of Tokyo metropolitan expressway were chosen because of the availability of traffic data collected round the clock, every minute from detectors which are on average 250 meters spaced.

Most RTCPMs studies are based on the detector data which are already installed and are fixed. For this reason, different approaches were taken by researchers to design the data collection process which effects the RTCPMs. As the construction of an RTCPM is computationally costly, it is not efficient if a model has to be built from scratch for every route and every detector layout. Additionally, instrumental failure of detectors are common. Hence rises the importance of a method to create uniformly distributed simulated detectors. A macroscopic model called cell transmission model (CTM) is adopted to serve this purpose. CTM takes traffic data from the existing detectors and divide it into 'cells' each of which consists of traffic flow data. Additionally, the CTM was modified to accommodate an intervention method called variable speed limit (VSL). The traffic data from CTM was compared to the existing detector data and it was found that the CTM can generate traffic flow data with an error of about 13%.

The performances and transferability of the CTMs were investigated by constructing RTCPMs. For RTCPMs, a machine learning method called Bayesian network (BN) and dynamic Bayesian network (DBN) was employed. Because, these methods are capable of adopting new traffic data and updating themselves. Moreover, BN has the property to handle missing data, which means, in case of instrumental failure, the model will still be able to predict crash likelihood with partially available data. These two are important properties to build a RTCPM. After validating the RTCPMs built with CTM generated data, it was found that the 11 out of 16 CTM-based RTCPMs (BN) outperformed the loop detector based RTCPMs, similar result was seen when RTCPMs were built with DBN.

VSL was chosen as an intervention method. Previously, in several studies VSL was applied to regulate traffic flow by limiting the allowable speeds on the road network. There are several situations when a lowering speeds could be effective, such as in situations of adverse weather, if an incident takes place at downstream, or congestion occurs in a specific segment of road etc. Different studies focused on objectives such as- reducing congestion, active traffic management, regaining bottleneck capacity on freeways etc. Few studies also focused on improving safety. Different strategies were selected by researchers to apply VSL. Still, there are some critical issues which have not been addressed such as- the optimum location of VSL control, duration of VSL control, transferability of the control strategy, effect of VSL control on crash risk. This thesis adopted deep learning methods called Q-learning (QL) and a deep reinforcement learning method called deep Q-learning (DQL). These methods getting popularity because of the model-free nature, which does not require to decide on a strategy for implementation, rather the model itself learns from its experience. To explain in brief, there is an 'agent' (the model) that observes different 'states' (traffic flow parameters, e,g, flow, speed, density etc.) and takes 'actions' (selects VSL values) in order to gain 'rewards' under a 'policy' (reducing crash risk). Hence, the model learns which VSL values are to be taken in which traffic condition to keep the crash risk under a threshold given. In this thesis, a crash risk threshold of 10 was chosen after investing RTCPM's performances and transferability in the earlier chapter. VSL was applied to a 0.90 km long segment of route 4 Shinjuku between Eifuku and Hatagaya with. By comparing both of the method with no speed control cases, it was found that the QL and DQL were able to improve the safety of the study location at the targeted segment where VSL was applied. In few cases, improvement at the upstream of the target location was also observed. By comparing the two method- QL and DQL, it was apparent that the DQL performed better than QL for the same study segment. The necessity of establishing a universal RTCP and intervention method is undeniable, considering it is data intensive, computational labor dependent. Although, the idea of a model-free intervention method is still a new concept, it has a potential towards the universal crash prevention method. The goal of this thesis was to go one step forward to achieve the universality of RTCP and intervention method.