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DYNAMIC PROGRAMMING BASED COORDINATED RAMP METERING ALGORITHMS

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ABSTRACT

Motorway congestion can be classified into two types, recurrent congestion and non-recurrent congestion. Recurrent congestion happens during peak hours. Non-recurrent congestion occurs due to car accidents, weather conditions or public events. Negative impacts of traffic congestion include wasted fuel, pollution, travel delay and spillover effects caused by slow traffic.

Ramp metering, as an only way to regulate traffic amount accessing to the motorway, is considered as the most cost-effective way to prevent the recurrent congestion. Coordinated ramp metering was developed to control a number of on-ramps simultaneously to improve traffic conditions on busy motorways. The existing coordinated ramp metering algorithms were normally established on macroscopic traffic flow models based on Payne's wok, the performances of which were measured by the employed macroscopic model themselves, and the released metering rates of which tended to be continuous. Implementations in microscopic traffic simulators were few.

This thesis presents DP (Dynamic Programming) based online control approaches for the optimal coordination of ramp metering and evaluates its performances in both macroscopic and microscopic traffic simulation environment. DP decision networks were proposed, where a traffic system can be modeled as a number of discrete traffic states and separated by time stages, and the control problem of coordinated ramp metering was treated as the minimization problem to search the optimal trajectory of discrete decision variables (ramp metering rates) that minimized a cost criterion in terms of TTS (total time spent) along the time horizon.

Experiments conducted in the macroscopic simulation environment demonstrated the full potential of proposed algorithms with precise queue constrains in an ideal deterministic environment, and experiments conducted in the microscopic simulation environment indicated the performances of the proposed algorithms in a stochastic environment and revealed the feasibility in the real world. The implementation of DP ramp metering was proposed under the framework of receding horizon control. A

6.7km stretch of motorway in Auckland, New Zealand, was chosen as a study location and constructed by a microscopic simulator as a simulation scenario and by a macroscopic traffic model as a prediction model. The simulation results indicated that the proposed algorithms were able to eliminate motorway queues under high traffic demands and manage queue lengths at metered on-ramps when queue constrains were not overstrict. The simulation results also revealed that 9 discrete metering rates for each ramp meter were adequate to prevent motorway queues. Such feature not only proved that the optimal trajectory converged very fast in the proposed DP decision networks, but also made on-line control system possible due to less computational load.

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NOMENCLATURE

1. Glossary

Speed (km/h): It, unless otherwise specified, refers to space mean speed in this thesis, and is measured as the average speed of all vehicles crossing a given length of motorway segment over a specified time period.

Density (veh/km/lane): The number of vehicles per unit length is measured along a given length of roadway segment.

Flow (veh/h): The number of vehicles is counted by a fixed detector over a certain time. *In macroscopic traffic models, speed, density, and flow are all related by a basic relation: the flow is equivalent to the product of speed and density.*

Occupancy (percentage): When a fixed detector was occupied by vehicles for a period of time, the percentage of occupied time in one detection interval is counted as occupancy. A rough conversation between density and occupancy can be given by: density is equivalent to occupancy divided by the average vehicle length. This conversion makes it possible that density can be measured at a fixed point.

Time headway (hour): Time headway is defined as, when two vehicles pass a fixed detector successively, the time period between the arrival of the front bumper of the first vehicle and the arrival of the front bumper of the succeeding vehicle.

Distance headway (km): Distance headway is defined as, when two vehicles pass a fixed detector successively, the distance between the arrival of the front bumper of the first vehicle and the arrival of the front bumper of the succeeding vehicle.

Capacity: The maximum possible flow at a point on the highway

Bottleneck: A location on the highway where the road capacity is a local minimum.

Congestion: A traffic condition under which vehicles travel slower than the drivers' desired speeds, restricted by the downstream conditions.

Critical density: The density value at which congestion may form at a point on the motorway.

Jam density: The density at which the traffic comes to a halt, i.e., the maximum density allowed at a point on the highway

Free-flow conditions: A traffic condition under which vehicles are able to travel freely at maximum allowed speeds.

Fundamental diagram: The functional relationship between the flow and density for a point on the highway.

Macroscopic model: A class of traffic models in which traffic is treated as a continuum and modeled by aggregated quantities such as density and flow.

Microscopic model: A class of traffic models in which dynamics of individual vehicle driver units and the interaction between these units and their surroundings are explicitly modeled, and the traffic itself is the collective behavior of all these vehicle driver units.

2. List of Symbols

The following symbols are only used to present glossaries above. More notations and definitions are given in Chapter 3.

v	*(km/hour)*	*Speed*
q	*(veh/hour)*	*Flow*
ρ	*(veh/km/lane)*	*Density (macroscopic model)*
k	*(veh/km/lane)*	*Density (fundamental diagram)*
v_f	*(km/hour)*	*Free flow speed*
k_{jam}	*(veh/km/lane)*	*Jam density (fundamental diagram)*
ρ_{jam}	*(veh/km/lane)*	*Jam density (macroscopic model)*
$k_{critical}$	*(veh/km/lane)*	*Critical density (fundamental diagram)*
$\rho_{critical}$	*(veh/km/lane)*	*Critical density (macroscopic model)*
r	*(veh/hour)*	*Ramp metering rates*

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