Theoretical Investigation of Traffic Flow: Inhomogeneity Induced Emergence

A dissertation presented in partial fulfillment of the requirements for the degree of

Doctor of Philosophy
in
Computer Science

at Massey University, Auckland, New Zealand

Mingzhe Liu

2010

Certificate of Regulatory Compliance

This is to certify that the research carried out in the Doctoral Thesis entitled "*Theoretical Investigation of Traffic Flow: Inhomogeneity Induced Emergence*" in the Institute of Information and Mathematical Sciences at Massey University, New Zealand:

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Supervisor: Prof. Ken Hawick

Signature:

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I dedicate this thesis and my love to my wife Ping Wen, my daughter Xiner Liu and my son Runxi Liu

Abstract

This research work is focused on understanding the effects of inhomogeneity on traffic flow by theoretical analysis and computer simulations. Traffic has been observed at almost all levels of natural and manmade systems (e.g., from microscopic protein motors to macroscopic objects like cars). For these various traffic, basic and emergent phenomena, modelling methods, theoretical analysis and physical meanings are normally concerned.

Inhomogeneity like bottlenecks may cause traffic congestions or motor protein crowding. The crowded protein motors may lead to some human diseases. The congested traffic patterns have not been understood well so far.

The modelling method in this research is based on totally asymmetric simple exclusion process (TASEP). The following TASEP models are developed: TASEP with single inhomogeneity, TASEP with zoned inhomogeneity, TASEP with junction, TASEP with site sharing and different boundary conditions. These models are motivated by vehicular traffic, pedestrian traffic, ant traffic, protein motor traffic and/or Internet traffic.

Theoretical solutions for the proposed models are obtained and verified by Monte Carlo simulations. These theoretical results can be used as a base for further developments. The emergent properties such as phase transitions, phase separations and spontaneous symmetry breaking are observed and discussed. This study has contributed to a deeper understanding of generic traffic dynamics, particularly, in the presence of inhomogeneity, and has important implications for explanation or guidance of future traffic studies.

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Contents

List of Figures

List of Tables