The Advanced Study Institute: Toward A New Generation of Dynamic Network Models

Hong K Lo (ASI Director), cehklo@ust.hk

Overall program

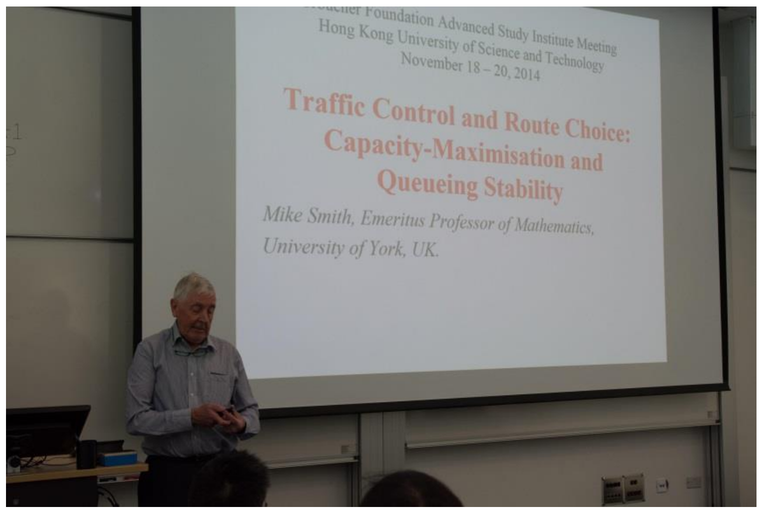
The Advanced Study Institute (ASI) on "Toward a new generation of dynamic network models" sponsored by the Croucher Foundation was successfully held on Nov 18-20, 2014 at the conference facility (Seminar room #2402) of the Institute of Advanced Study of the Hong Kong University of Science and Technology. The program book of this ASI is attached as Appendix A of this report, and the website providing more information about the workshop can be found at http://www1.ce.ust.hk/asi-2014/index.html

Overall, the ASI comprised of three whole-days of lectures and presentations, with the lectures from overseas lecturers delivered in the mornings, presentations from participants in the afternoons, and roundtable discussion at the end of each day to wrap up and summarize findings. This ASI was able to bring together top-notch researchers in the field for sessions of active and productive discussions of issues that should be addressed to advance the field forward, which were instrumental in defining the research agenda for the future.

<u>Participation</u>

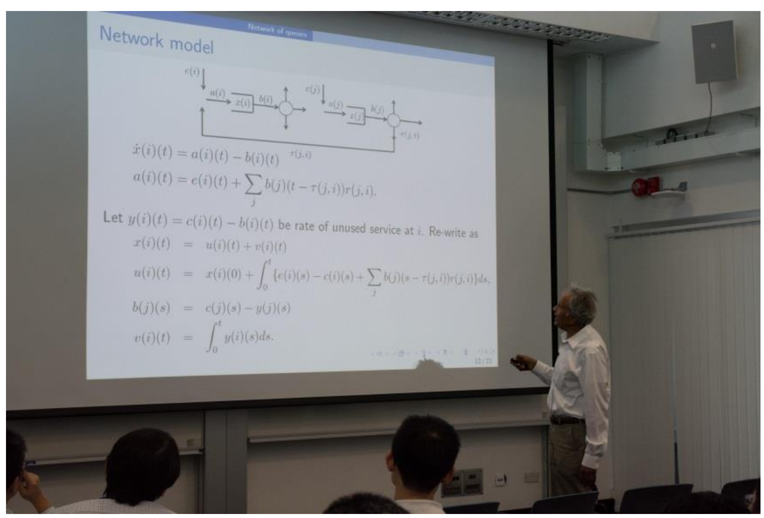
Five overseas lecturers, including Professors Martin Hazelton, Takamasa Iryo, Henry Liu, Mike Smith, and David Watling, delivered their 90-minute lectures and actively engaged in the 3-day workshop.

We also invited more than ten participants from the region to make presentations and engage in the discussion at this ASI. Together with local and non-local participants, all together we had 65 participants.



<u>Scholarly Publications</u>

In terms of publication of the papers presented, we have gained an agreement with the top journal *Transportation Research Part B* to publish a special issue on "Day-to-Day Dynamics in Transportation Networks" based on papers presented in this ASI. The deadline for paper submission is Jan 15, 2015, and the expected publication date is the end of 2015.



APPENDIX A

THE CROUCHER FOUNDATION ADVANCED STUDY INSTITUTE

TOWARD A NEW GENERATION OF DYNAMIC NETWORK MODELS

Nov. 18-20, 2014   Hong Kong

Sponsers:

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THE CROUCHER FOUNDATION ADVANCED STUDY INSTITUTE
TOWARD A NEW GENERATION OF DYNAMIC NETWORK MODELS

Nov 18-20, 2014

The Hong Kong University of Science and Technology

The Hong Kong Society for Transportation Studies

Preamble

The notion of equilibrium has been driving transportation network modeling and planning for the past few decades since the origin of this field. Equilibrium analysis has its appeal, is relatively simple and can be described by a set of well-defined mathematical expressions. Recently, there has been resurgence of interest in developing a deeper understanding of the dynamical system approach for modeling transportation systems, perhaps motivated by studies that question the existence of equilibrium, its uniqueness, stability, and attraction domains. Moreover, many contend that understanding the process or trajectory toward equilibrium is just as important as it involves understanding the learning process and behavioral adaptations, and such an understanding is instrumental for transportation management. It suffices to say that many aspects simply cannot be answered by traditional equilibrium analysis. The main goal of this Advanced Study Institute (ASI) is to look beyond the traditional equilibrium analysis and explore a new approach toward modeling dynamic networks, which will open up theoretically interesting, yet practically important directions for modeling and managing dynamic transportation networks.

In this three-day ASI, we cover mainly five topics pertaining to five aspects of moving the dynamical system approach forward for dynamic network modeling.

1. Dynamical models with stochastic processes (Professor David Watling)
2. Calibration and data issues for day to day dynamic models (Professor Martin Hazelton)
3. Dynamical models for modeling network disruptions (Professor Henry Liu)
4. Dynamical interaction between traffic control and route (mode) choice (Professor Mike Smith)
5. Dynamical interaction between travel choice adjustment and information sharing (Professor Takamasa Iryo)

In addition to these five topics, we also invite presentations from Hong Kong and the region to enrich the discussion and interactions, and to bring up a new generation of transportation network scientists. Participants are invited to make presentations on the dynamical system approach for modeling transportation network, including topics both in theory and innovative applications to real-world problems.

At the end of each day, we will hold a roundtable discussion of issues and problems addressed on that day. The objective is to develop some common themes to formulate a research agenda to move forward the dynamical systems approach for modeling transportation networks.

We have arranged an agreement with *Transportation Research Part B* to publish a special issue on "Day-to-Day Dynamics in Transportation Networks" based on papers presented in this ASI.

Acknowledgement

The financial sponsorship of the Croucher Foundation is gratefully acknowledged, as is the support from the HKUST Jockey Club Institute for Advanced Study. This Advanced Study Institute is co-organized by the Department of Civil and Environmental Engineering of the Hong Kong University of Science and Technology and the Hong Kong Society for Transportation Studies.

Organizing Committee:

- Prof. William H.K. Lam, The Hong Kong Polytechnic University
- Prof. Janny M.Y. Leung, The Chinese University of Hong Kong
- Prof. Hong K. Lo (ASI Director), Hong Kong University of Science and Technology
- Dr. W.Y. Szeto, University of Hong Kong
- Prof. Pravin Varaiya, Hong Kong University of Science and Technology, and University of California, Berkeley
- Prof. S.C. Wong, University of Hong Kong
- Prof. Hai Yang, Hong Kong University of Science and Technology

Campus Map

Institute for Advanced Study
The Hong Kong University of Science of Technology

SESSION SCHEDULE

Nov 18, 2014
Venue: 2/F Seminar Room (#2042), Institute of Advanced Study, The Hong Kong University of Science and Technology (HKUST)

10:30 - 10:50	Registration
10:50 – 11:00	Welcome address Hong K Lo
11:00 - 12:30	The Stochastic Process Approach to Modelling Changing Transportation Systems: Basic Principles and Challenges for Real-Life Implementation David Watling
12:30 - 2:00	Lunch
2:00 - 2:40	Bayesian Learning, Information Provision, and Stability of Network Equilibrium Shoichiro Nakayama
2:40 - 3:20	Day-to-Day Flow Dynamics with User Learning Hongbo Ye, Feng Xiao, Hai Yang
3:20 - 3:40	Refreshment Break
3:40 - 4:20	Day-to-day path flow dynamics and user heterogeneity Zhijia Tan, Hai Yang, Ren-yong Guo
4:20 - 5:00	Re-visit of Traffic Assignment Algorithms in terms of Convergence Seungjae Lee, Jooyoung Kim, Shinhae Lee
5:00 - 5:30	A roundtable discussion on the outlook and major issues in model development, if tackled, would substantially improve the ability and realism of this approach David Watling

Nov 19, 2014

Venue: 2/F Seminar Room (#2042), Institute of Advanced Study, The Hong Kong University of Science and Technology (HKUST)

9:00 - 10:30	Calibration and data issues for day to day dynamical models Martin Hazelton
10:30 - 11:00	Refreshment Break
11:00 - 12:30	Understanding the Traffic Evolution Process after Network Disruption: A Boundedly Rational Behavioral Approach Henry Liu
12:30 - 2:00	Lunch

2:00 - 2:40	A Markovian assignment model considering stochastic traffic demand Sun Huijun, Han Linghui
2:40 - 3:20	Day-to-day traffic dynamics: evolution under forever changes and uncertainties, and its implications for traffic management Jing Bie, Hong K. Lo
3:20 - 3:50	Refreshment Break
3:50 - 4:30	Steady state analysis of traffic equilibriums with demand and supply regulation strategies: Stable games and advanced control notions Renxin Zhong, Dabo Xu and Can Chen
4:30 - 5:30	A roundtable discussion on the data requirements and the need of creating a common database to allow for model comparison and validation Martin Hazelton

Nov 20, 2014

Venue: 2/F Seminar Room (#2042), Institute of Advanced Study, The Hong Kong University of Science and Technology (HKUST)

9:00 - 10:30	Traffic Control and Route Choice: Capacity Maximisation and Queueing Stability Mike Smith
10:30 - 11:00	Refreshment Break
11:00 - 12:30	Dynamical interaction between travel choice adjustment and information sharing Takamasa Iryo
12:30 - 2:00	Lunch
2:00 - 2:40	Analysis of Fixed-time Control Pravin Varaiya
2:40 - 3:20	Day-to-day route choice with social interactions Yu Xiao, Hong K Lo
3:20 - 3:40	Refreshment Break
3:40 - 4:20	Tradable credit scheme for control of day-to-day traffic flows Ren-Yong Guo, Hai-Jun Huang , Hai Yang
4:20 - 5:00	Modelling day-to-day travellers’ route choice and level of trust in traveller information using real-time estimated traffic state Afzal Ahmed, David Watling, Dong Ngoduy
5:00 - 5:30	A roundtable on priority of research and implementation questions for moving forward the dynamical systems approach for dynamic network modeling Hong K Lo

The Stochastic Process Approach to Modelling Changing Transportation Systems: Basic Principles and Challenges for Real-Life Implementation

David Watling
Institute for Transport Studies, University of Leeds

Abstract

The presentation has two main objectives. Firstly, it aims to introduce the stochastic process approach for representing dynamics and uncertainty in transportation systems. This introduction is aimed at those unfamiliar with such an approach, and builds on only a basic understanding of mathematical techniques and statistics. Simple ‘toy’ examples will be used to illustrate the principles, and to explain what the approach might be useful for, and how it compares with traditional equilibrium analyses.

Secondly, it addresses: what are the challenges in implementing such a method on large, real-world transportation systems, i.e. in taking the method from theory into practice? In answering this question, many sub-questions arise. What data sources and calibration tools might we need? What are the conceptual challenges in matching real-world phenomena with elements of the model? How does the interpretation of the model components relate to what we can use it for in transport appraisal? In addressing these questions, the aim will be to identify what we can do with known techniques, and where we may need to focus future research attention.

Bayesian Learning, Information Provision, and Stability of Network Equilibrium

Shoichiro Nakayama
Institute of Science and Engineering, Kanazawa University, Japan

Abstract
From the viewpoint of traffic management, it is particularly important to appreciate the conditions under which network flow is stable or unstable. Possible methods of examining the problem are to analyze the stability of a determined equilibrium or to investigate the day-to-day dynamics of actual network flow that consists of learning drivers. It is natural that Bayesian learning is adopted if drivers are substantially rational. In this study, we assume that drivers under day-to-day dynamic transportation circumstances choose routes based on Bayesian learning and develop a day-to-day dynamic model of network flow. This model reveals that a driver using Bayesian learning chooses the route that frequently takes the minimum travel time. Furthermore, we find that the equilibrium point of the day-to-day dynamic model is identical to Wardrop's equilibrium. Under complete information (when information about which route takes the minimum travel time is given after the trips), Wardrop's equilibrium is globally asymptotically stable and the day-to-day dynamic system converges to Wardrop's equilibrium if initial recognition among drivers is distributed widely. Under incomplete information, Wardrop's equilibrium is always globally asymptotically stable regardless of what the drivers' initial recognition is. Paradoxically, the condition for stable equilibrium under incomplete information is more relaxed than that under complete information.

Day-to-day flow dynamics with user learning

Hongbo Ye
Department of Civil and Environmental Engineering, The Hong Kong University of Science and Technology, Clear Water Bay, Kowloon, Hong Kong, PR China

Feng Xiao
School of Transportation & Logistics, Southwest Jiaotong University, Chengdu, PR China

Hai Yang
Department of Civil and Environmental Engineering, The Hong Kong University of Science and Technology, Clear Water Bay, Kowloon, Hong Kong, PR China

Abstract

Xiao et al. (2013) constructed a second-order flow-based day-to-day dynamics derived from a combined model of flow and perceived cost. The second-order dynamics was analyzed by analogizing to a damped oscillation system: “mass” and “energy” of the day-to-day dynamic traffic network was defined, the intrinsic properties such as “angular frequency”, “damping ratio” and system stability were discussed. However, discussion on the possible negative path flows was excluded in their paper: the nonnegativity of path flows was assured by a strong assumption but not the flow evolution process itself. This paper relaxes the assumption of positive path flows in the day-to-day model proposed by Xiao et al. (2013) which simultaneously considered travelers’ learning and route switching behavior. With nonnegative-path-flow constraints, evolution trajectories of the day-to-day dynamics become discontinuous. As a result, the flow dynamics with regard to flows and perceived costs cannot be converted to an equivalent second-order ordinary equation set anymore, and the analogy in Xiao et al. (2013) cannot be conducted. With separable link travel time functions, we show that the dynamic path flows still converge to Wardrop’s user equilibrium path flow set. Rigorous proof is established based on a generalized invariance theorem with a piecewise continuous Lyapunov function. Stability and some other system properties are examined by numerical examples.

Keywords: Day-to-day dynamics; user learning; discontinuous evolution process

Day-to-day path flow dynamics and user heterogeneity

Zhijia Tan
School of Management, Huazhong University of Science and Technology, Luoyu Road 1037, Wuhan, PR China

Hai Yang
Department of Civil and Environmental Engineering, The Hong Kong University of Science and Technology, Clear Water Bay, Kowloon, Hong Kong, PR China

Ren-yong Guo
College of Computer Science, Inner Mongolia University, Hohhot 010021, PR China

Abstract

This paper investigates evolutionary implementation of congestion pricing schemes to minimize the system costs measured in either monetary or time units with the consideration of the travelers' day-to-day route adjustment behavior and their heterogeneity. The travelers' heterogeneity captured by their value-of-times is a natural but challenge issue since different travelers' perceived travel utility with different values of travel time in a tolled transportation network. We propose a general model framework to characterize the behavior of route adjustment of travelers in a tolled transportation network with multiple user classes and investigate its stability issue. Furthermore, dynamic congestion pricing schemes to drive the system towards social optimum in terms of minimization of total monetary or time cost of the whole network are examined.

Keywords: dynamic pricing; user heterogeneity; day-to-day flow dynamics; traffic equilibrium; stability

Re-visit of Traffic Assignment Algorithms in terms of Convergence

Seungjae Lee and Jooyoung Kim
University of Seoul

Shinhae Lee
Seoul Institute

Abstract

Recently, faster algorithms to solve the traffic assignment problems have been proposed in order to overcome the zigzagging slow convergence in the Frank-Wolfe algorithm. The papers have argued that the Frank-Wolfe algorithm cannot solve a true equilibrium solution while the faster path or origin based algorithms reach a true solution. The consequences of these arguments can lead how we can view, and overcome the gap between the theoretical and practical aspects of link based and path or origin based algorithms. In theory, it has been proven that the link based traffic assignment algorithm has a stable uniqueness solution, and the Frank-Wolfe algorithm can solve the stable unique solution. On the other hand, the path based algorithms (including origin based algorithms) give rise to multiple solutions in theory even in the standard and separable traffic assignment problem. In order to give a reasonable solution among multiple solutions in the path based algorithms, a proportionality index can be used to indicate if the assigned volumes in the used paths have a good proportionality irrespective of numbers of paths, and origin and destination pairs.

In this paper, we have compared the convergence of some advanced algorithms embedded in commercial software in order to solve the equilibrium road traffic assignment. We have tested traffic assignment algorithms in Emme, Cube and Transcad. The advanced algorithms are a path based algorithm (Emme), a conjugate algorithm (Cube) and an origin-based algorithm (Transcad). Convergence performances are compared from simple contrived networks to large scale networks. In simple contrived networks, we can test if the algorithms are able to converge into a known solution. This analysis can lead to see if the link and path or origin based algorithms can solve a stable unique solution. We can also test if these algorithms have a good proportionality index in terms of number of alternative paths, and origin and destination pairs. In large scale networks, we can test if the algorithms calculate reasonable solutions by comparing base scenario and do-alternative scenario, which is one of the motivations for this paper. Some recent studies mentioned the poor convergence in the standard Frank-Wolfe algorithm can lead an inconsistency in convergence values. Therefore, major investigation of this paper is in a feasibility study to build an alternative road if the inconsistent convergence in the algorithms between base and do-alternative scenario lead to different travel time saving benefits. The convergence criteria are a relative gap and a proportionality index. We have found that the algorithms can be comparable in terms of these criteria.

Keywords: Convergence Analysis, Uniqueness, stability, Proportionality, Frank-Wolfe Algorithm, Origin Based Algorithm, Path Based Algorithm, Conjugate Algorithm.

Calibration and data issues for day-to-day dynamic models

Martin Hazelton
Massey University, New Zeland
M.Hazelton@massey.ac.nz

Abstract
The practical application of dynamic traffic models requires us to address a variety of statistical inference problems. Perhaps the most obvious of these is estimation of model parameters in order to ensure appropriate calibration for the particular traffic system that is being studied. Also critical are methods for model comparison and goodness-of-fit testing. All these types of statistical inference tend to be challenging because available data for traffic systems (e.g. link counts) are frequently only indirectly related to the parameters of interest (e.g. mean route flows). The situation is especially difficult for dynamic day-to-day models because many of the most interesting properties of the model (e.g. parameters describing the ways in which travellers obtain, process and react to information on past states of the network) are particularly hard to estimate. Even when seemingly informative data are available (e.g. through vehicle tracking technologies), problems of sampling bias typically need to be resolved.

The last 15 years have witnessed a sea change in research on parameter estimation in the transport literature, with ad hoc methods giving way to more principled statistical techniques. In particular, the rise of Markov Chain Monte Carlo (MCMC) methods that rely on sampling of latent variables (e.g. route flows) has provided a general framework for implementing theoretically well founded methods of statistical inference (within both Bayesian and Frequentist paradigms). Nonetheless, a large number of challenges remain. These include (i) theoretical analysis of parameter identifiability for day-to-day dynamic models (i.e. working out which models we can hope to fit using available data, and which we cannot); (ii) development of efficient MCMC samplers for general day-to-day models; (iii) methods for handling combinations of data types (some subject to bias); (iv) examination of methods of model comparison; (v) development of computationally cheap approximations based on quasi-likelihoods, for use on large systems; and (vi) principled methods of calibrating micro-simulation models.

In this talk I will review recent progress on statistical inference for network-based traffic models, leading to the description of a unified framework for parameter estimation and model testing. I will then attempt to provide some pointers as to how the challenges listed above might be tackled. In particular, I will describe some very recent developments with regard to challenges (i)-(iii), and will speculate on possible research avenues for (iv)-(vi).

Understanding the Traffic Evolution Process after Network Disruption: A Boundedly Rational Behavioral Approach

Henry Liu
Department of Civil and Environmental Engineering & Transportation Research Institute
University of Michigan, Ann Arbor

Abstract

Understanding the traffic evolution process after an unexpected network disruption is of great significance to traffic engineers who are responsible for traffic restoration. In this talk, we will discuss our findings on the day-to-day traffic equilibration process following the unexpected collapse and eventual reopening of the I-35W Bridge over the Mississippi River in Minneapolis. Following the I-35W Bridge collapse, drivers were observed to drastically avoid areas near the disruption site until the perceived congestion in that area gradually diminished. After the reopening of the disrupted link, despite a complete restoration of network topology, empirical evidence suggested that less people used the new bridge. To explain this, we developed a nonlinear dynamical system that is capable of describing the transient states of a disrupted network, answering questions related to the traffic evolution trajectory from a disequilibrium (due to a network disruption) toward an equilibrium. We also investigated why travelers would not use the new bridge even if it could save their commute time. We found that, although perfect rationality is usually assumed in route choice models, such classical approach fails to explain travelers' route choice behavior observed in the I-35W bridge collapse case. In our models, travellers are assumed to be boundedly rational. In other words, travelers do not always take the shortest paths but their chosen routes have the travel time deviating from the shortest paths within a threshold. Though the BR travel behavioral concept was proposed in the 1980's, empirical validation of such behavioral principle using real-world data along with a theoretical framework was non-existent. This research will bridge these gaps from both empirical and theoretical perspectives.

A Markovian assignment model considering stochastic traffic demand

Sun Huijun, Han Linghui
School of Traffic and Transportation, Beijing Jiaotong University, Beijing 100044, China

Abstract
In real traffic network, both link capacity and traffic demand are subject to stochastic fluctuations. These random fluctuations can make travel time uncertain. All existing dynamical models considering the uncertainty of travel time are presented with fixed traffic demand. In this study, we present a Markovian assignment model with stochastic traffic demand. The traffic demand is grouped into two parts-commuters with fixed traffic demand and irregular travelers with discrete random demand. With wild conditions, we prove that our Markovian assignment model is ergodic and has unique stable distribution. We also give an algorithm to describe the Markovian model. By numerical test, we analyze the effect of commuters' memory length, irregular travelers' demand and commuters' perceived error on the stable distribution of our model.

Day-to-day traffic dynamics: evolution under forever changes and uncertainties, and its implications for traffic management

Jing Bie
Department of Civil Engineering
University of Nottingham Ningbo China

Hong K. Lo
Department of Civil and Environmental Engineering, The Hong Kong University of Science and Technology, Clear Water Bay, Kowloon, Hong Kong

Abstract
In this paper we provide a generalized framework for capturing the characteristics of day-to-day traffic dynamics. The inter-day evolution is formulated as a dynamical system problem, which also takes into account the changes of traffic network over time as well as the intrinsic uncertainties in (perceived) network performance.
Changes are persistent in our traffic network because the physical infrastructure never remains the same. Weather and road conditions are constantly affecting the capacity or 'supply' of road networks. Changes also occur due to weather events, traffic accidents, or even the introduction of traffic management measures such as road pricing. For a realistic representation of the day-to-day traffic dynamics, it is imperative to integrate traffic dynamics with 'network dynamics'. This paper provides a comprehensive categorization of various network changes (e.g. naturalistic vs. induced, random vs. systematic, incidental vs. recurrent, shock vs. shift) as well as how they can be accounted for in our formulation.
Demand fluctuates as well. More importantly, demand evolves. Demand, imposed on a forever changing supply, results in a dynamical system which by appearance may look rather random or chaotic but in essence represents an evolutionary process. During repeated daily trips, the decision making (departure time, mode, routing) goes through a learning process, updated whenever new experience and/or knowledge are gained. However, no one is perfect and perception is often biased. Uncertainty in perception is coupled with bounded rationality in behavior. This paper adopts a general approach accommodating different behavioral models in choice and learning.

Based on our dynamical system formulation, we show that the conventional equilibrium as a "state" (or a probabilistic distribution of states) can be replaced by an "equilibrium process", thus incorporating the temporal dimension and resolving some of the discrepancies in equilibrium definition. Moreover, we are able to demonstrate a few issues that are of particular interest to dynamic traffic management, which is no longer "target"-oriented but more "process"-oriented. Examples include: (a) Irreversible network change occurs when a "shock" to the system, i.e. a temporary change, causes permanent effects. This implies that sometimes changes cannot just be 'undone' to restore original system; on the other hand, traffic managers can introduce short term measures to induce long term impact; (b) Sequential traffic management measures can be employed by applying a series of changes onto the system in order to reach the target scenario, which a single change would not achieve; (c) Flexibility in traffic management measures often arises given that travelers are boundedly rational. This implies that there exists certain freedom or leeway for the traffic manager to test different measures or to optimize the measure by trial and error.

Keywords: Network change; Bounded rationality; Equilibrium process; Dynamic traffic management; Irreversibility; Sequential measures; Management flexibility

Steady state analysis of traffic equilibriums with demand and supply regulation strategies: Stable games and advanced control notions

Renxin ZHONG
Research Center of Intelligent Transportation Systems, School of Engineering, Sun Yat-Sen University, Guangzhou, China

Dabo XU
School of Automation, Nanjing University of Science and Technology, Nanjing, China

Can CHEN
Research Center of Intelligent Transportation Systems, School of Engineering, Sun Yat-Sen University, Guangzhou, China

Abstract

This paper introduces an interconnected dynamic system approach to address the convergence and stability issues of traffic adjustment processes in presence of demand (e.g. market based road pricing and tradable travel credit schemes) and supply (e.g. signal timing, queue control and other schemes that can be modeled by side constraints) regulations. The proposed framework intends to answer the following questions related to the basic assumption of static traffic assignment models, i.e. the system operates at its steady state:

- Is it possible to establish a bridge to connect the short-term (dynamic within-day) models and the long-run (static) models?
- Given a set of demand and supply regulation strategies, whether the traffic on a network would approach to a steady state based on certain assumptions for behavioral realism?
- How to model the demand variation (or uncertainty) due to exogenous elements rather than the demand elasticity under the umbrellas of conventional traffic assignment and road pricing frameworks?

To the best of the author's knowledge, no model has been proposed to describe such kind of steady state analysis. If affirmative answers to these questions can be obtained, then the dynamics is mathematically consistent with the axiom of static user equilibrium, namely, after a sufficient long time of evolution, the traffic network will eventually reach a steady-state user equilibrium. On the other hand, if the traffic flow adjustment process of a traffic network under a certain set of demand and supply regulations cannot evolve towards a stable traffic equilibrium, it is interesting and of importance for us to look into the problem that how can we adjust the demand and supply regulations so that the traffic flow of the network would evolve towards stable traffic equilibria eventually. Most of the papers addressing long-term dynamics and stability of transportation networks assume that the traffic network is a closed system and isolated from the environment such that the system is "unforced" and the system trajectory is defined by the initial condition and the prescribed traffic management schemes. However, a traffic network cannot be isolated from the environment but interacts with it. One of the major reasons for understanding long-term traffic evolution dynamics is to control or influence the system trajectory in some way. The planner may also wish to influence the traffic dynamics to the most desirable trajectory by adjusting the demand and supply regulation schemes with respect to its interaction with the environment, e.g. the demand uncertainty due to economic environment and inaccurate cost measurement. The final part of this paper aims to deal with this problem by introducing some advanced control notions. Travel demand is assumed to be uncertain but bounded from above. Unlike the isolated case, wherein (global) stability results can be obtained (in terms of link based dynamics), practical stability can be achieved when there is uncertainty. Finally, we present several numerical simulations to validate the main results.

Keywords: Interconnected dynamic system, stability & convergence, disequilibrium dynamics, traffic regulation scheme, uncertainty, traffic equilibrium.

Traffic control and route choice: capacity maximization and queueing stability

Mike Smith
Department of Mathematics, University of York, Heslington, York, UK

Abstract
Part 1 of this paper presents idealised natural general and special dynamical models of day-to-day re-routeing and of day to day green-time response. (In these, route-flows only swap to cheaper routes and stage green-time only swaps toward more pressurised stages.) The green-time response models are based on the responsive control policy P0 introduced in Smith (1979a, 1987). It is shown that, for any steady feasible demand within a flow model, if the general day to day re-routeing model is combined with the general day to day green-time response model then under natural conditions any (flow, green-time) solution trajectory cannot leave the region of supply-feasible (flow, green-time) pairs and costs are bounded. It is also shown that if the special re-routeing model is combined with the special green-time response model then every (flow, green-time) solution trajectory converges to a non-empty set of equilibria consistent with the P0 control policy. Throughput or network capacity is maximised: given any constant feasible demand; this demand is (i) met on each day as any allowed routeing / green-time trajectory evolves and also (ii) met at any stationary point of the combined routeing - green-time response model. Such a stationary point is a user equilibrium which is consistent with the P0 green-time control policy; guaranteed to exist under natural conditions. Part 2 of the paper then shows that, within a simple day to day model with queues and just one junction, a modified Varaiya (2013) responsive control and a modified version of a responsive control designed by Le at al (2013) do not have these properties. It is shown that (with each of these two modified control policies) there is a steady demand within the capacity of the simple network for which there is no equilibrium consistent with the control policy. These modified policies are not queue-stabilising when drivers' route choices are allowed for. In contrast, it is shown that using responsive P0 on this example network does maximise throughput at a quasi-dynamic user equilibrium consistent with P0, and yields bounded queues along all allowed trajectories. This result is extended to allow for certain time-varying demands; and then further rather speculatively extended toward possible new "backpressure" traffic control policies.

Keywords: Traffic Control and Route-Choice, Capacity maximization, Queueing Stability

References
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Dynamical interaction between travel choice adjustment and information sharing

Takamasa Iryo
Department of Civil Engineering, Kobe University

Abstract
It is natural to assume that travellers would make their choices depending on information provided by other travellers as well as their own past experiences. For example, in the past literature, a day-to-day dynamical model has been referred to as a model that explicitly models 'the system adjustment mechanism including user's memory and learning process' (Cascetta and Cantarella, 1993) or a behavioural model considering 'how the behaviour on day n is affected by behaviour and the state of the network on days n−1 and earlier' (Watling and Hazelton, 2003). These descriptions of day-to-day dynamical models did not directly mention that travellers obtain information provided by someone else. However, it is apparent that travellers in these models need to collect information from someone else to learn situations of a network because they cannot experience all the choices (e.g. route choices) and know their details (e.g. travel time) at the same time. If they just rely on their own experience, they need to change their choices quite often to experience many choices available in a system. This seems not realistic, especially when travellers do not recurrently make choices (e.g. destination choices for sightseeing).

Considering how information is shared among travellers is important to construct a day-to-day dynamical model that is consistent with their microscopic behaviour. Although many day-to-day dynamical models have been proposed in the area of transport studies, it is not common to incorporate microscopic information search behaviour of travellers into a model explicitly. A model including microscopic behavioural model is beneficial when we need to consider how far (or whether) the performance of a transport system becomes better when a new information provision tool is introduced to distribute information to travellers who attempt to make a choice. Note that improving an information provision system may result in a situation in which travellers will fail to obtain sufficient information to select a better choice (Iryo et al., 2012), and hence examining effect by improving information transmission is important to estimate whether it is beneficial or not.

This talk provides three topics related to information sharing in day-to-day dynamical models. First, a few selected past studies of day-to-day models are introduced to understand how they (explicitly or implicitly) incorporate a mechanism of information sharing among travellers. Then, a day-to-day dynamical model that explicitly incorporates information search behaviour of travellers is explained. Lastly, an in-room experiment that investigated people's information search behaviour is introduced to understand how far the model represents actual microscopic behaviour of travellers.

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Analysis of FT Control

Ajith Muralidharan
Sensys Networks, Inc, Berkeley, CA 94710
amuralidharan@sensysnetworks.com

Ramtin Pedarsani
University of California, Berkeley, CA 94720-1770
ramtin@berkeley.edu

Pravin Varaiya
University of California, Berkeley, CA 94720-1770
Corresponding Author, varaiya@berkeley.edu, 1-510-642-5270

Abstract

T A network of signalized intersections is modeled as a queuing network. The intersections are regulated by fixed-time (FT) controls, all with the same cycle length or period, T. Vehicles arrive from outside the network at entry links in a deterministic periodic stream, also with period T, make turns at intersections in fixed proportions, and eventually leave the network. Vehicles take a fixed time to travel along each link, and at the end of the link they join a queue. There is a separate queue at each intersection for each movement. The storage capacity of the queues is infinite, so there is no spill back. The state of the network at time t is the vector $x(t)$ of all queue lengths, together with the position of vehicles traveling along the links. The state evolves according to a delay-differential equation. Suppose the network is stable, that is, $x(t)$ is bounded. Then

(1) there exists a unique periodic trajectory $x^*(t)$, with period T;
(2) every trajectory converges to this periodic trajectory;
(3) if vehicles do not follow loops, the convergence occurs in finite time.
The periodic trajectory determines the performance of the entire network.

Keywords: Fixed-time control, periodic solution, store-and-forward model, queueing network, global asymptotic stability, delay-differential equation

Day-to-day route choice with social interactions

Hong K. Lo
Department of Civil and Environmental Engineering, The Hong Kong University of Science and Technology, Clear Water Bay, Kowloon, Hong Kong
cehklo@ust.hk

Yu Xiao
Department of Civil and Environmental Engineering, The Hong Kong University of Science and Technology, Clear Water Bay, Kowloon, Hong Kong
yxiaoac@ust.hk

Abstract
Existing studies usually model route choice by assuming that travelers have identical and complete information about the performance of transportation network, although the perceived error of travel time is considered in some of them. In reality, this condition might be a strong assumption and somewhat unrealistic. Without external traffic information, a traveler may only know the travel time of her own choice. Even after the applications of public traffic information systems, travelers may receive or use information from different sources. On the other hand, we noticed that with the prevalence of social media and location-aware mobile devices, the social interactions among travelers become unprecedented frequent, and the crowd-sourcing traffic information applications have been developed and got huge number of users. Under this circumstance, due to the discrepancy of the status of travelers in their social networks, they receive different information about the performance of the transportation network, and then make best responses based on available information. In this study, we target to model the day-to-day route choice with social interactions. Consider a traveler with m friends, with proportion of choosing each route being $p = (p_1, \cdots, p_i, \cdots p_R)$, R is the total number of routes. Then the set of her friends is treated as a sample of the whole group of travelers, and she infers the global performance based the sample information, the perceived error is modeled by logit model. We formulate the evolution of two-route choice problem with social interaction, and use three kinds of typical network structures (lattice network, small world network, and fully connected network) to illustrate the influence of social network information on the day-to-day route choice. The result shows that travelers' choices and the transportation network performance at stable status will be significantly influence by the discrepancy of received information.

Keywords: route choice, social network information

Tradable credit scheme for control of day-to-day traffic flows

Ren-Yong Guo
College of Computer Science, Inner Mongolia University, Hohhot 010021, PR China

Hai-Jun Huang
School of Economics and Management, Beihang University, Beijing 100191, PR China

Hai Yang
Department of Civil and Environmental Engineering, The Hong Kong University of Science and Technology, Clear Water Bay, Kowloon, Hong Kong, PR China

Abstract
Most tradable credit schemes published so far are implemented in a traffic network at equilibrium state. In this paper, we propose a dynamic tradable credit scheme for control of day-to-day evolution process of traffic flows towards stationary equilibrium state. Travelers obtain the credits from the traffic authority. On each day, travelers using a link have to pay a certain number of credits. They choose routes according to the previous day's travel time costs and intraday credit costs that are determined by link credit charge and credit price. During each period covering a number of days, the authority announces a fixed credit price by considering the relationship of supply and demand of credits in the previous period. The day-to-day adjustment process of link flows and credit price evolution constitute a dynamic game between authority and travelers. It is expected that the link flow pattern and credit price will ultimately evolve to a Nash equilibrium state.

Doubly interactive dynamics between traffic flow adjustment and credit price evolution is formulated as a dynamical system. Several properties of the proposed dynamical system under certain preconditions are investigated, including the consistence of stationary user equilibrium (UE) state and credit trading equilibrium (CTE) state, the existence of stationary link flow pattern and credit price, the uniqueness of stationary link flow pattern, the boundness and convexity of the set of stationary credit prices, and the convergence of day-to-day adjustment process. Moreover, the effects of dynamic tradable credit scheme on revenues of both authority and travelers are analyzed, and a rule to distribute credits among all users in the day-to-day process is proposed. Finally, numerical results on both a simple network and a middle-size network are presented to show the application of the proposed dynamic tradable credit scheme and to demonstrate the properties of the dynamical system. This study is helpful for narrowing the gap between the theory of tradable credit scheme and its application to reality.

Keywords: Traffic dynamics, tradable mobility credits, user equilibrium, credit trading equilibrium

Modelling day-to-day travellers' route choice and level of trust in traveller information using real-time estimated traffic state

Afzal Ahmed
Institute for Transport Studies, University of Leeds, Leeds LS2 9JT, United Kingdom

David Watling
Institute for Transport Studies, University of Leeds, Leeds LS2 9JT, United Kingdom

Dong Ngoduy
Institute for Transport Studies, University of Leeds, Leeds LS2 9JT, United Kingdom

Abstract

Real-time traffic state estimation techniques have been widely used to determine a more reliable picture of existing traffic condition along a traffic network. Traffic state estimated based on estimation algorithm such as Kalman filter is more accurate than the prediction using traffic flow model or measurements from the sensors. On the other hand, the existing applications of dynamic traffic assignment (DTA) models are based on either traffic flow models based on historic information or real-time measurements from the sensors, whereas estimated traffic state can capture the dynamics in network capacity or travel demand more accurately. This research is aimed to combine the applications of DTA models with estimated traffic state based on real-time measurements.

In this paper we propose a framework to utilize real-time traffic state estimation technique to model day-to-day dynamics of traffic flow on the network with provision of real-time traveller information with time-varying traffic demand. The traveller information is predicted based on real-time estimated traffic state. We also propose to model the level of trust in the information as a dynamic parameter, as commuter's level of trust in ATIS increases with the accuracy of the information provided. The proposed framework for combining DTA with real-time estimated traffic state is also applied for within day application of DTA for incident management.

For numerical illustration, the proposed framework is applied to a hypothetical traffic network with time-varying traffic demand. The travel times for the ATIS are predicted based on real-time estimated traffic state, which combines prediction from the cell transmission model (CTM) and real-time observations from measurement sensors in extended Kalman filter (EKF). Commuters update their perception about expected travel time based on their past experience and real-time information provided by the ATIS and make the decision about en-route choice. The results of numerical experiment show a significant improvement in network performance and saving of commuter's travel time with the proposed framework.