Abstracts

PUBLIC LECTURE

Cheap solutions to the transport problem
Mark Wallace (Monash University and Opturion)
The term rush hour is out-of-date: morning traffic congestion in Melbourne lasts from 6:30 until 9:30am. The annual cost of congestion to Victoria is estimated to rise from $3 billion to $6 billion by 2020. It is estimated that more than 20,000 trucks move through Melbourne's inner west each day, but the East-West Link project - an 18-kilometre inner urban road connecting the Eastern Freeway and the Western Ring Road - would help reduce this traffic. It will cost $13 billion (so far $15M for writing the business case). Eddingtons 2008 rail and road recommendations cost $18 billion. Mathematicians in Melbourne are exploring another way to keep traffic flowing on the existing roads and rails. Mathematical control of new traffic lights at the M1 freeway entrances, has already increased the M1 capacity by 3000 vehicles per hour. This is merely a small improvement compared with the traffic revolution currently taking place.
The new generation of vehicle communication systems will enable vehicles to drive faster and closer together with lower risk. This could increase traffic throughput by a factor of four. A broader vision is to schedule all transport. Suppose you notified the transport system each time you started a journey, then it could schedule your road use to balance out traffic across the road system and minimise congestion. Simulations show that even with a small percentage of drivers using the system, users could reach their destination in half the time.
The majority of freight in Melbourne goes on small vans. Just by introducing a small number of transfer points, so that vans are used more efficiently, simulations indicate an immediate 25% reduction in van road usage. Public transport take-up in Melbourne is limited because buses are too few and far between, so mathematicians are developing adaptable bus schemes using communication devices and scheduling algorithms to make sure theres a bus where and when you need it.
Mathematics will make it possible to solve Melbournes transport problem without spending tens of billions of dollars on new infrastructure. The costs will be closer to just writing the business case for the infrastructure investment!

Behavioural foundations of two-fluid model for urban traffic
Vinayak Dixit (The University of New South Wales)
Traditionally traffic flow models have been based on analogous physical phenomena. Though these models have been successful in representing traffic flow, there is a need to provide a systematic behavioural explanation for their existence. One such model is the two-fluid model which is analogous to the principles of Bose-Einstein condensation of particles at low temperatures. The model has been extensively used to characterize the quality of traffic on urban networks and arterial streets. The two parameters of the model essentially represent free flow travel time and level of interaction among vehicles. Though the studies have found the parameters of the two-fluid model to be significantly correlated with driver behaviour (aggressive/conservative) and crash rates, no systematic behavioural explanation has been found. This paper proposes a behavioural framework based on individual trade-off behaviour to explain the two-fluid model phenomenon. The two-fluid model is derived based on a drivers attempt to maximize his quality of travel, by traveling fast while maintaining safety. Contrary to earlier assumptions the proposed framework shows the two parameters to be correlated. The theoretical framework was tested using two-fluid model data from various cities. The data was also used to estimate the effects of geometric factors on the perception of likelihood of a crash and the severity of the crash that affect the two-fluid model. Increase in the fraction of one-way streets was found to reduce the drivers perception of likelihood to crash. While reduction in the fraction of one way streets and increase in average number of lanes per street, signal density and fraction of actuated signals increased the perceived level of severity of a crash.

Rail scheduling for the hunter valley coal chain
Andreas Ernst (CSIRO)
Gaurav Singh; Antonio Gomez-Iglesias
The Hunter Valley Coal Chain is one of the largest coal export supply chains in the world. A critical part of the infrastructure is the rail network. Coal has to be taken from many different mines on the network to the three terminals at the Port of Newcastle. Using the available network and trains efficiently is a significant challenge. This talk describes the scheduling problem that arises when creating daily schedules for the trains. A parallel matheuristic approach for solving this problem will be described together with numerical results showing the effectiveness of our method.

Some new approaches in bilevel optimization
Jörg Fliege (University of Southampton)
Huifu Xu; Konstantinos Kaparis
Some problems related to transportation networks can naturally be formulated as bilevel optimization problems, where a decision maker has to take into account the responses of some users to his decisions. Examples include selection of links for capacity improvements (network design), pricing of freight transportation services (toll setting) and traffic signal setting. We present new approaches for bilevel optimization, derived from an optimality condition for the lower level problem that leads naturally to one or more nonsmooth equality constraints. Two different approaches will be considered, one of them generalizable to lower level multiobjective problems, the other generalizable to lower level variational inequalities. We consider various semismoothness results for both types of approaches, and provide preliminary numerical results on standard bilevel problems that outline the efficacy of both of them.

Coordinated emergency evacuation
Heng-Soon Gan (The University of Melbourne)
Mingzheng Shi; Kai-Florian Richter; Stephan Winter
Evacuation of a region can often be affected by road congestions, especially for regions with restricted road access. Road congestions cause unwarranted delays and can introduce further distress amongst evacuees. Congestion issues during an emergency evacuation can generally be dealt with at two levels, namely the planning phase, and realtime control and coordination. In this talk, we will discuss a coordination strategy to tackle road congestions during the planning phase. We will consider the case of evacuating the Olinda region (Dandenong Ranges) via coordination of evacuees' exit locations and evacuation start times. The coordination strategy is developed using a mixed-integer linear program, and verified using a traffic (micro)simulation platform.

A comparative study of Macroscopic Fundamental Diagrams of arterial road networks governed by adaptive traffic signal systems
Tim Garoni (Monash University)
Lele Zhang; Jan de Gier
Using a stochastic cellular automaton model for urban traffic flow, we study and compare Macroscopic Fundamental Diagrams (MFDs) of arterial road networks governed by different types of adaptive traffic signal systems, under various boundary conditions. In particular, we simulate realistic signal systems that include signal linking and adaptive cycle times, and compare their performance against a highly adaptive system of self-organizing traffic signals which is designed to uniformly distribute the network density. We find that for networks with time-independent boundary conditions, well-defined stationary MFDs are observed, whose shape depends on the particular signal system used, and also on the level of heterogeneity in the system. We find that the spatial heterogeneity of both density and flow provide important indicators of network performance. We also study networks with time-dependent boundary conditions, containing morning and afternoon peaks. In this case, intricate hysteresis loops are observed in the MFDs which are strongly correlated with the density heterogeneity. Our results show that the MFD of the self-organizing traffic signals lies above the MFD for the realistic systems, suggesting that by adaptively homogenizing the network density, overall better performance and higher capacity can be achieved.

Managing traffic flow on urban road networks
Adrian George (VicRoads)
The structural elements and operation of the Melbourne urban road traffic network is described. This network is a highly structured, highly developed network controlled predominantly by signalised intersections. Current practice in managing traffic flows is described, based on the SCATS traffic control system which controls most of the 3,000 sets of traffic lights, using dynamic allocation of time to match traffic demands in terms of competing paths, volumes, and directional bias. Some aspects of using signal control to improve freeway traffic flow are also discussed. Aspects of network traffic management that are not well understood are described, providing an overview of possible research areas that could inform and improve management practices.

A mixed logit modelling approach to investigating at-fault accidents
Kelvin Goh (Monash University)
Currie, G.; Sarvi, M.; Logan, D.
Accident models in road safety research is typically developed based on the assumption that parameters are fixed across observations, e.g. a group of road intersections with comparable geometrical and traffic characteristics are taken to be similarly correlated to accident risks. In reality, heterogeneity across observations may exist. Risk perception, for instance, is likely to vary across drivers. In this study, the potential of using a mixed logit modelling approach, which allows for parameters in the model to vary, is demonstrated through the development of an at-fault model for bus drivers in Melbourne.

A primer in traffic flow modeling and management
Serge Hoogendoorn (Delft University of Technology)
Traffic flow theory finds its roots in the work of Bruce Greenshields, who in 1934 published his seminar paper on the so-called fundamental diagram, a relation between traffic density and volume, which turned out to be pivotal in modeling traffic flows.
Since then, the field has been infused by contributions from various fields, such as physics, psychology, engineering, informatics, and mathematics, showing its truly multidisciplinary nature.
This talk deals with quantitative methods in the modeling and control of traffic flows in networks, ranging from predicting freeway traffic operations, to the management of huge crowds during the Hajj.
In particular, the talk focuses on the various fascinating phenomena that are observed in traffic flow (self-organization, capacity drop, wide moving jams), the various approaches to the mathematical modeling of these phenomena (microscopic models, continuum models), and the use of these models for state estimation, prediction and control. In doing so, the lecture will pinpoint the key mathematical challenges that either have been or need to be resolved. This will be done by showing several theoretical examples and practical applications in road traffic and crowd management, and evacuation planning.

Implications of patterned interactions in complex systems for the structure of decision making organization
Mohsen Jafari Songhori (The University of Melbourne)
Most of organizational, social, and technological systems are considered as sets of interdependent decisions. However, these models typically assume that the interactions among decisions are distributed randomly. Contrarily, the empirical studies of real socio-technological systems show that interactions among decisions are highly patterned. Patterns such as small-world, power-law distributions, and preferential attachment are some examples. Besides this fact, organizations (e.g. teams, companies, supply chains) handling such patterned systems are collections of fallible/bounded-rational decision-makers. These organizations structure can vary from a centralized (hierarchy) to decentralized (polyarchy). In the former structure, a proposal needs to be validated by successive ranks of the hierarchy to be approved. In the later structure, approval by any one actor in a parallel series of decision-makers is sufficient for an alternative to be approved.
This paper examines the implications of the pattern of interactions among decisions of a system for the structure of organization that should handle such a system. An Agent-Based NK simulation model of socio-technological system

is generated. Furthermore, by holding the total number of interactions among decisions fixed, the performance of organizations with centralized and decentralized are compared and investigated. Examinations of the results of simulation revealed that the centralized organizations do better for systems with some particular patterns among decisions. However, some other patterns favour an organization with a decentralized structure. The paper finishes with a summary of findings.

Assessment of positioning accuracy for cooperative intelligent transportation systems
Allison Kealy (The University of Melbourne)
Intelligent transportation systems (ITS) have emerged in response to the major transportation challenges for society today. At the core of any ITS is the positioning and communications systems used to connect people, vehicles, etc. As ITS evolve and become safety critical, it is essential that the performance levels (accuracy, integrity and availability) required is assured. This paper focuses on the positioning technologies that will inform future ITS. It presents the computational techniques for positioning based on signals from Global Satellite Navigation Systems (GNSS) such as the Global Positioning System (GPS) and describes developments over the next decade which will add satellite constellations from Europe, China, India and Japan. This paper will expose the weaknesses of using satellite positioning alone for ITS and propose an integrated computational framework based around Kalman filtering and map matching to combine both GNSS and non-GNSS signals, to meet the stringent requirements for safety critical applications.

Linear-quadratic model predictive control for urban traffic networks
Tung Le (Swinburne University of Technology)
Hai L. Vu; Yoni Nazarathy; Bao Vo; Serge Hoogendoorn
Advancements in the efficiency, quality and manufacturability of sensing and communication systems are driving the field of intelligent transport systems (ITS) into the twenty first century. One key aspect of ITS is the need for efficient and robust integrated network management of urban traffic networks. This paper presents a general model predictive control framework for both centralized traffic signal and route guidance systems aiming to minimize network congestion. Our novel model explicitly captures both non-zero travel time and spill-back constraints while remaining linear and thus generally tractable with quadratic costs. The end result is a central control scheme that may be realized for large urban networks containing thousands of sensors and actuators.

A distributed real-time optimisation approach suited to traffic signalling
William Moase (The University of Melbourne)
Ronny Kutadinata; Chris Manzie
Model-based approaches for traffic signal control are limited due to the lack of accurate low-order models for urban traffic networks. Extremum-seeking (ES) is a class of non-model based real-time optimisation approaches that aim to drive the inputs of a dynamical system to the values that optimise the measured performance of that system in the steady state. As such, ES appears to be a promising solution for traffic signal control; however, as the number of inputs to a given system increases, the task of designing an ES scheme that delivers adequate performance becomes increasingly difficult. This makes the deployment of ES on large urban traffic networks a particularly challenging task. This presentation will: introduce the audience to a simple class of ES scheme; explain how it could be used for the control of traffic signals; and will show how recently developed results for distributed ES solves issues associated with the high-dimensionality of urban traffic networks.

Jamology - traffic jams of self-driven particles
Katsuhiro Nishinari (The University of Tokyo)
Jamming phenomena are seen in various transportation system including cars, buses, pedestrians, ants and molecular motors, which are considered as “self-driven particles’. There is universality of jam formation among various sorts of flows. We recently call this interdisciplinary research on jamming of self-driven particles as “jamology”. This is based on mathematics and theoretical physics, and and includes engineering applications as well. In the talk, starting

from the background of this research, a simple mathematical model, called the asymmetric simple exclusion process (ASEP), is introduced as basis of all kinds of traffic flow. Applications to the vehicle and pedestrian flow are discussed based on extended models of the ASEP. Comparisons between theory and our various experiments are also given with jam solution ideas.

Modelling and simulation of bushfire evacuation scenarios with refuge options
Jan Richter (IBM Research Australia)
Kent Steer; Anton Beloglazov; Ziyuan Wang
The traffic modelling group of IBM Research Australia undertook a study into the dynamics of an evacuation of residents from the Victorian country town of Millgrove. The primary objective was to explore and understand the difference, in terms of traffic conditions on the Warburton Highway, between the establishment of a single fire-safe refuge, or the establishment of two such refuges. The study utilised a set of evacuation planning tools, currently under development by IBM Research Australia, that enable the modelling, simulation, and analysis of neighbourhood evacuation scenarios in a much shorter time frame. A second evacuation study in the area of the Dandenong ranges is in progress also focussing on the impact of refuges on the evacuation dynamics.

An opportunistic client user interface to support centralized ride share planning
Michael Rigby (The University of Melbourne)
Antonio Krüger; Stephan Winter
Existing ride-sharing systems for commuting in urban environments are rigid. They rely on the communication of spatio-temporal constraints from both vehicle and client to perform ride-matching. From a client user perspective these approaches are problematic, leading to location-privacy issues and the use of additional communication channels for ad-hoc negotiation which cannot be immediately quantified. To account for these important aspects, we develop a dynamic, intuitive interface technique known as launch pads and a centralized system architecture, which together simplify the ride-matching process whilst preserving location-privacy. The results of two experiments, vehicle service coverage and client probability of pick-up, reveal the latent potential existing within ride-sharing systems if vehicle flexibility is quantified and incorporated into a representation of accessibility. We argue that communication of this potential using launch pads and our architecture provides a client with means to fully exploit this potential and interface with ride-sharing more effectively, thus providing proof of concept of our approach.

A quantitative measure for the lifetime analysis of transport networks
Majid Sarvi (Monash University)
A new measure is introduced to analyse and evaluate the performance of transport networks. It is a measure of growth and shift in traffic load that a network can sustain. The traffic growths considered are linear traffic growth and traffic shift in the network towards more attractive traffic zones. The benchmark for network performance/reliability assessment is based on a metric such as travel time, level of service or amount of transport emission. The proposed measure is applied to a large network to demonstrate its scalability and capability in identifying the weakest elements (links) in the network. Various strategies such as road pricing and capacity enhancement were examined and the results were analysed to demonstrate the capability of the proposed methodology. It is believed that this measure is useful both in the planning phase of new transport networks and in the performance and reliability analysis of the existing networks.

Three case studies of traffic flow modelling with real traffic data
David Shteinman (The Australian Centre for Commercial Mathematics at UNSW)
CASE STUDY 1
Area Network or Perimeter Control is the arterial analogy of ramp metering on freeways. It utilizes the concept of smart metering of vehicles into a congested network using the relationships between variables that characterize the network performance: space mean flow, density and speed of the network.

We report on collaborative projects underway involving the Australian Centre for Commercial Mathematics, the Urban Transport Systems Laboratory at EPFL (Switzerland), RMS and Vicroads to validate and implement the theory of Area Network Control in real arterial networks. These are the first case studies to use real signalized intersection data with a view to implementation in the existing arterial control system by adding a large-scale coordination component.
CASE STUDY 2
Road Authorities are required to supply quantitative evidence of a performance improvement due to a change in some feature of the traffic network. While there may be subjective or anecdotal evidence of the new systems success, data-based quantification of improvement is difficult to obtain due to the noise within the system and the presence of confounding variables.
We present a novel approach to this problem by adapting a method used in environmental science: the “Before After Control Impact method”(BACI) was originally developed for detecting impacts in complex environmental systems. BACI is combined with advanced statistical estimation methods to give a robust methodology that can assess traffic changes and their causes in a noisy system. A case study is presented of the BACI approach used to assess the impact on traffic flows of a change to a railway boom-gate system in the Melbourne arterial network.
CASE STUDY 3
The ANTTS travel advisory service provides a real-time estimate of travel times on the F3 freeway from Sydney to Newcastle, for journeys of various lengths along the freeway in both directions. These estimates are provided to road users via overhead signs on the freeway, based on data collected from e-tag readers along the F3.
We summarize a wide-ranging project conducted by the ACCM for RMS of NSW to identify statistical issues with the current system and provide recommendations for the resolution of these issues. While there is a large literature on travel time prediction using advanced statistical approaches, these have not yet been implemented by traffic authorities worldwide. Statistical issues investigated included methods for outlier filtering, reporting metrics, sample size or the proportion of vehicles actually captured by the e-tag readers, the problem of a time lag especially for long trips entering peak hour and the highly variable predictions for low density data (overnight).

Road safety modelling using a safety analysis chain: A theoretical discussion
Amir Sobhani (ITS at Monash University)
Road safety analysis has been focus of researchers for decades. There have been numerous studies conducted to understand the main factors affecting roads safety level. These studies have been very critical since they improved our understanding of traffic crashes and the main factors involved in crash causation. This presentation outlines a new theoretical framework as a basis for future research on road safety modelling and understanding. Then, a modelling method is introduced to model safety performance of intersections using the proposed framework. Finally, some guidelines for future research will be provided.

Optimization over transportation networks
Pascal Van Hentenryck (NICTA and University of Melbourne)
This talk reviews how to apply modern optimization techniques to a number of applications in disaster management and large-scale supply chains. Their impact on the practice in field is also discussed.

Large scale traffic modelling from city planning to emergency evacuations
Jürg von Känel (IBM Research Australia)
Anton Beloglazov; Jan Richter; Kent Steer; Ziyuan Wang
As more and more people live in cities, planning for the handling of increasing traffic volumes becomes a crucial capability. Determining whether or not a new road will deliver the desired relieve to congestion is one of the crucial questions in that space. Using a large scale, agent based traffic simulator allows to explore the outcomes of such changes. We have such a simulator, capable of simulating millions of cars and their drivers behaviours. For regular city planning purposes - assumptions such as most people are driving from an origin with a given destination in mind are common, and people only make detours if they have to - but still want to reach their given destination. This simulator was built by our Tokyo Research lab with city planning in mind and has been used for Tokyo, Hiroshima, Beijing,

Rio and some other city planning. With appropriate adaptations such a simulator can also be applied for emergency evacuations. The work done in the traffic modelling area fits into IBM Research's broader endeavour of building a system of systems which combines different models, data, and algorithms for faster and more efficient decision support. This goal aligns with the Australian Disaster Management Platform (ADMP), a collaboration between the University of Melbourne, NICTA, and IBM Research Australia.

Real-time route guidance in stochastic networks

Hai Vu (Swinburne University of Technology)
Wei Dong; Bao Vo; Yoni Nazarathy; Serge Hoogendoorn

We develop a simple framework for the problem of finding the least expected travel time route from any node to any given destination in a stochastic and time-dependent network. Both spatial and temporal link travel time correlations are considered in the proposed solution that is based on a dynamic programming approach. In particular, the spatial correlation is represented by a Markovian property of the link states where each link is assumed to experience congested or uncongested conditions. The temporal correlation is manifested through the time-dependent expected link travel time given the condition of the link traversed. The framework enables a route guidance system where at any decision node within a network, one can make a decision based on current traffic information about which node to take next to achieve the shortest expected travel time to the destination. Numerical examples will be presented to illustrate the framework and to demonstrate the effectiveness of the solution

Transport network equilibrium models incorporating adaptivity and volatility

Travis Waller (The University of New South Wales)

The goal of this talk is to summarize certain classes of network modelling tools in the transport domain and provide an insight into emerging techniques. To begin, a broad summary of multiple recent and ongoing research topics conducted by the speaker in the transport network modelling sub-field will be provided including dynamic network assignment, mesoscopic traffic modelling and dynamic network routing. Critical domain considerations and applicability will be noted as they relate to the underlying methodological development. Then, recent research developments related to stochastic routing and adaptive equilibria will be presented in the context of real-time traffic behaviour in the presence of information. New algorithms for the online shortest path problem form the core methodological contribution for the new models as well as a resulting set of convex mathematical programs which provide novel insights not previously obtainable with previous modelling tools.

Collaborative transportation: a case for computational transportation science

Stephan Winter (The University of Melbourne)

Collaborative transportation, a term that does not yet exist in Wikipedia, aims to reduce the consumption of some resources (such as fares, time, energy, pollution, street space) by the collaboration of people, vehicles and operators over the movement of people or freight. Collaborative transportation always existed, based on social agreements or conventions, but becomes even more attractive in increasingly connected environments where sensors track mobility demand as well as actual movements, and communicate this in real time.

Collaborative transportation challenges computational transportation science (Winter et al., 2010) in many ways, among them scalability, real-time and near-future planning, economic modelling, and persuasive human-computer interaction. Since collaborative transportation is inherently inter-modal these challenges require an understanding of the fundamental principles of the collaborative transportation system: the representation, analysis and interaction of the components of collaboration, independently from a particular transportation mode.

Since mobility is fundamentally bound to space and time, in this talk I will investigate the core concepts identified to capture the specialties of space and time (e.g., Egenhofer, 1993; Kuhn, 2012) for their role in the context of collaborative transportation. The concepts themselves are bound to some fundamental laws of geographic information science (Goodchild, 2009; 2011; Sui and Goodchild, 2011) that will suggest operations and axioms (constraints) in collaborative transportation.

References

Egenhofer, M. J. (1993): What's special about spatial? Database requirements for vehicle navigation in geographic space. ACM SIGMOD Record, 22 (2): 398-402.
Goodchild, M. F. (2009): What problem? Spatial autocorrelation and geographic information science. Geographical Analysis, 41 (4): 411-417.
Goodchild, M. F. (2011): Challenges in Geographical Information Science. Proceedings of the Royal Society A, 2011 (467): 2431-2443.
Kuhn, W. (2012): Core concepts of spatial information for transdisciplinary research. International Journal of Geographical Information Science, 26 (12): 2267-2276.
Sui, D. Z.; Goodchild, M. F. (2011): The Convergence of GIS and Social Media: Challenges for GIScience. International Journal of Geographical Information Science, 25 (11): 1737-1748.
Winter, S.; Sester, M.; Wolfson, O.; Geers, G. (2010): Towards a Computational Transportation Science. ACM SIGMOD Record, 39 (3): 27-32.

Traffic disruption and recovery in road networks
Lele Zhang (Monash University)
Tim Garoni; Jan de Gier
Using a stochastic cellular automaton model for multilane links with one lane blocked, we study the impact of traffic disruptions induced by e.g., vehicle breakdown and road work, and the recovery process after the disruption is removed from the system. The analytical discussion shows that the domain wall model can reproduce the time evolution of flow and density during the loading and the recovery processes of the disruption for traffic networks.