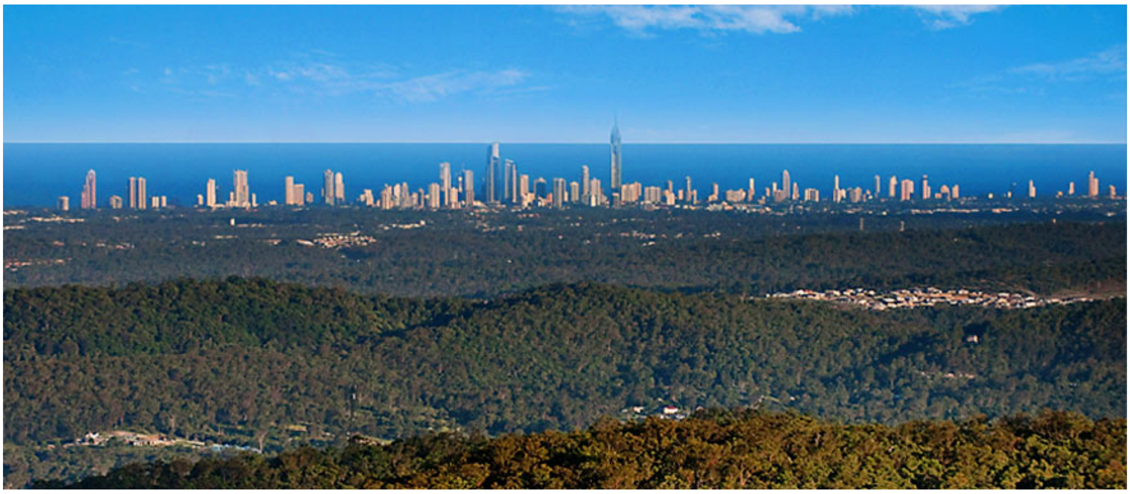
Queues, Modelling, and Markov Chains:

A Workshop Honouring Professor Peter Taylor

Mount Tamborine, 28-30 June 2019

Hobart November 2015, where Peter found Ψ



View from Eagle Heights

Organisers: Azam Asanjarani, Nigel Bean, Mark Fackrell, Sophie Hautphenne, Radislav Vaisman, Ilze Ziedins
Webpage: Ross McVinish

Schedule

Friday 28 June

14:00 Transport from Brisbane

18:00 Cocktail party, Bistro, Eagle Heights Mountain Resort

Saturday 29 June

9:00 Meet and greet

9:20 Welcome

9:30 **I** Jerzy Filar (2), Jing Fu (2), Joshua Ross (7). Chair: Rhys Bowden

11:00 Morning Tea

11:30 **II** Gideon Weiss (8), David Stanford and Ilze Ziedins (8). Chair: Yoni Nazarathy

13:00 Lunch

14:00 **III** Qi-Ming He (4), Sophie Hautphenne (3), Yiqiang Zhao (9). Chair: Matthieu Simon

15:30 Afternoon Tea

16:00 **IV** Ruth Williams (9), Paul Keeler (4), Stella Kapodistria (4). Chair: Laleh Tafakori

19:00 Dinner at Eagle Heights Mountain Resort

Sunday 30 June

9:00 **V** Moshe Haviv (3), Sarah Dendievel (1), Nigel Bean (1). Chair: Binyamin Oz

10:30 Morning Tea

11:00 **VI** Peter Glynn (2), Giang Nguyen (7), Guy Latouche (5). Chair: Eleonora Deiana

12:30 Lunch

13:30 Excursion (Skywalk)

15:30 Afternoon Tea

16:00 **VII** Michel Mandjes (6), Ellen Muir (7), Masakiyo Miyazawa (6), Nelly Litvak (5). Chair: Azam Asanjarani

18:00 Short speeches and closing

Monday 1 July

11:00 Transport to Brisbane, including visit to Daisy Hill Koala Centre

Abstracts

Intensive Care Units resuscitate my interest in queueing theory

Nigel Bean
The University of Adelaide

A few years ago, I undertook what I expected to be a pretty straightforward queueing analysis of an Intensive Care Unit in Adelaide. However, an accidental discovery that the arrival process and service times were not independent turned that completely upside-down! Discussions with the doctors left us uncertain about the cause, but convinced that there was some degree of queue-management being undertaken. We are slowly making progress with developing better models that we hope will shed light on the true causes. The models we are exploring are based on QBDs that enable the dependence between the arrival process and the service times to be included.

I'll motivate the talk by the original problem and briefly indicate the analysis we did to discover the dependence between the arrival process and the service times. I'll spend the rest of the talk discussing the models we have developed and critically review the insights that arise from these models.

Fellow travellers on this journey:
Original analysis and discovery of the dependence: Jo Varney and Mark Mackay
Improved modelling: Sarah James and Jono Tuke.

Analysis of two-class queueing models with interclass-correlated arrivals

Sarah Dendievel
Ghent University

We consider a queueing model with one single infinite waiting room, two servers and two classes of customers, each having their own dedicated server. The classes of two consecutive customers arriving in the waiting room are dependent in a Markov way: two consecutive customers belong to the same class with probability α. This type of dependence is called *interclass-correlation* in the arrival stream. Customers are served on a first-come, first-served basis. This may cause a blocking effect: a class clustering in the arrivals may block customers of the other class arriving later in the waiting room regardless of the state of the other class' server. In this paper, we analyze the impact of the cluster parameter α on the performance of the two-server queueing model with random and bounded service times.

This is joint work with Herwig Bruneel.

Threshold Risk and Uncertainty Quantification in Environmental Modelling

Jerzy A. Filar
The University of Queensland

Mathematical models of environmental problems often demand understanding of complex dynamics and interactions between many physical and biological variables on the one hand, and human inputs on the other. Uncertainties accompanying such models stem from multiple sources. Sometimes they manifest themselves as cascading errors and at other times they involve the risk of key variables crossing undesirable thresholds. In both cases they undermine confidence in either the model or, worse still, the underlying science. We discuss these issues with illustrations from certain generic areas such as models of fishery management and integrated climate change models.

Resource allocation and competition - examples and problems

Jing Fu
The University of Melbourne

We study a resource allocation problem with different requests, and with resources of limited capacity shared by multiple requests. We model this problem as a set of heterogeneous Restless Multi-Armed Bandit Problems (RMABPs) connected by the constraints imposed by the resource capacity. Following the idea of Whittle relaxation, and the asymptotic optimality proof of Weber and Weiss, we propose a simple policy for our problem and prove that it is asymptotically optimal if and only if a certain condition holds. This result can help model resource allocation problems in virtual network embedding, wireless network slicing, Cloud/Fog computing, healthcare patient scheduling and ride-sharing transportation.

This work is joint with Bill Moran and Peter Taylor.

A Monte Carlo Algorithm for Solving Perron-Frobenius Eigenvalue Problems

Peter Glynn
Stanford University

In this talk, we discuss the use of sampling-based methods that exploit regenerative representations for the Perron-Frobenius eigenvalue, eigenfunction, and eigenmeasure for an irreducible non-negative operator. We discuss the central limit theory for these estimators, and their implications for rates of convergence and construction of confidence intervals.

This work is joint with Paritosh Desai.

How old is that bird?
The age distribution under some phase sampling schemes

Sophie Hautphenne
The University of Melbourne

We consider a model for a bird population in which the lifetime of each bird follows a phase-type distribution with transient phases $1, 2, ..., m$ and absorbing phase 0. The phases do not necessarily have any particular physical interpretation. The model allows us to compute several interesting features such as the expected number of birds in each phase at time t, or the asymptotic frequency of each phase.

In an attempt to translate these features so that they can be viewed in terms of age-classes instead of phases, we need to be able to answer questions of the type "what is the conditional age distribution of a bird given its phase?" This problem may be tackled in several ways, depending on how we define the observation scheme. In this talk I will present and compare some of them.

This is joint work with Melanie Massaro and Peter Taylor.

A busy period approach to queueing games

Moshe Haviv
The Hebrew University of Jerusalem

The traditional approach when looking for a symmetric equilibrium behavior in a queueing system, is to look for a strategy, which if used by all, then under the resulting steady-state conditions, it is also one's best response. We suggest an alternative approach. It says that one interacts, or may interact, only with those who share with one the busy period one belongs too. This leads to a normal form symmetric non-cooperative game with a typically random number of players. In particular, when a player assesses the number of actual participants (him inclusive), he assumes that it is the length bias distribution of the number of arrivals during a single busy period. We then use the same approach, while defining the concept of social cost of deviation (SCoD), in order to characterize symmetric socially optimal strategies. A few illuminating examples are given.

This is joint work with Binyamin Oz.

Moment bounds of PH distributions with infinite or finite support based on the steepest increase property

Qi-Ming He
University of Waterloo

The steepest increase property of phase type (PH) distributions was first raised in O'Cinneide (1999) and was proved in O'Cinneide (1999) and Yao (2002), but since then it got little attention in the research community. In this work we demonstrate that the steepest increase property can be applied for proving previously unknown moment bounds of PH distributions with infinite or finite support. Of special interest are moment bounds free of specific PH representations except the size of the representation. For PH distributions with infinite support, it is shown that such a PH distribution is stochastically smaller than or equal to an Erlang distribution of the same size. For PH distributions with finite support, a class of distributions which was introduced and investigated in Ramaswami and Viswanath (2014), it is shown that the squared coefficient of variation (SCV) of a PH distribution with finite support is greater than or equal to $1 = (m(m+2))$, where m is the size of its PH representation.

This is joint work with Gabor Horvath, Illes Horvath, and Miklos Telek.

Decision making under uncertainty

Stella Kapodistria
Eindhoven University of Technology

We consider a class of stochastic dynamic programming (SDP) problems arising in the context of maintenance. Such SDP problems aim at deriving optimal policies (when should maintenance be performed and by how much should the system be maintained). From a fundamental perspective, the difficulty of such SDP problems lies in deriving the optimal policy. From a numerical perspective, the difficulty lies in computing the policy (the curse of dimensionality). While, from a practical perspective, the difficulty lies in the stochastic modelling of all the relevant information (big data). In this talk, we present an overarching framework that aims at addressing all aforementioned challenges.

Determinantal point processes and applications

Paul Keeler
The University of Melbourne

Point processes are essentially collections of points randomly scattered on some underlying mathematical space. Determinantal point processes form an interesting class of these objects due to their mathematical properties. Starting around the 1960s, researchers in (mathematical) physics discovered special cases of these point processes, but in recent years they have enjoyed renewed interest in fields such as probability, telecommunication engineering, spatial statistics and machine (or statistical) learning. In this talk, I will give a brief overview of determinantal processes and discuss how they can serve as mathematical models.

About matrices that come in pairs

Guy Latouche
Université Libre de Bruxelles

Performance measures of Quasi-Birth-and-Death processes (QBDs) are characterised by two matrices, usually denoted as G and R. In discrete time, G is the matrix of transition probabilities from some level n to the level $n-1$ immediately below, and R is the matrix of expected sojourn time in level $n+1$, starting from level n, under taboo of level n. For unrestricted QBDs, the ones allowed to move without restriction in negative as well as positive levels, two more matrices may be defined: $\widehat{G}$ which is the matrix of transition probabilities from level n to level $n+1$ and the matrix $\widehat{R}$ of expected sojourn time in $n-1$, starting from level n, under taboo of the initial level.

The matrices G and $\widehat{R}$ are closely connected in many ways: they are both about levels below the level occupied at time 0, they are algebraically similar, and they are solutions of nearly identical equations. For that reason, we shall write here that $(G, \widehat{R})$ forms a pair. Similarly, $(\widehat{G}, R)$ forms a pair.

The same holds for fluid queues and for Markov modulated Brownian motion, although the physical meaning of G and $\widehat{R}$ (and $\widehat{G}$ and R) need to be adapted to the fact that levels are continuous. For M/G/1-type Markov chains, we have a pair $(G, \widehat{R})$ but no pair $(\widehat{G}, R)$ because of the process being allowed to jump from level n to a level higher than $n+1$ and, similarly, we have a pair $(\widehat{G}, R)$ for GI/M/1-type Markov chains but no pair $(G, \widehat{R})$ since the process may jump in the negative direction.

Fluid queues, QBDs, etc. are all special cases of Markov additive processes — for which similar pairs exist in the absence of jumps. To a large extent, Markov additive processes and the menagerie of special cases have been analysed in different spirits, and it is interesting to try and reconcile the different results. I shall focus in this presentation on the characteristic equation for G and $\widehat{R}$.

This is based on joint work with Jevgenijs Ivanovs and Peter G. Taylor.

Inclusive mathematics

Nelly Litvak
University of Twente and Eindhoven University of Technology

Imagine that a TV presenter casually mentions“multi-dimensional spaces”, and everybody understands. We live in the digital era and our daily lives depend on numbers. Yet, the general public has little to no idea what exactly the role of mathematics is and why they need to learn it. In this talk I will discuss how we could talk about mathematics with literally everyone – from people with technical education to those who have long ago decided that ‘math is not their thing’. The talk is based on my experience as a popular science author and on other related activities, such as giving public lectures and running a Facebook group about mathematics for non-mathematicians with 14000 participants. I will share my observations with you, often surprising to myself.

Estimating the input of a Lévy queue by Poisson sampling of the workload process

Michel Mandjes
University of Amsterdam

In this talk I'll discuss semi-parametric estimation of the input process to a Lévy-driven queue by sampling the workload process at Poisson times. The approach relied upon is of method-of-moments type, aiming at estimating the Lévy process' characteristic exponent. It exploits the known distribution of the workload sampled at an exponential time, thus taking into account the dependence between subsequent samples. Verifiable conditions for consistency and asymptotic normality are provided, along with explicit expressions for the asymptotic variance. The method requires an intermediate estimation step of estimating a constant (related to both the input distribution and the sampling rate); this constant also features in the asymptotic analysis. For subordinator Lévy input (minus a deterministic drift), a partial MLE is constructed for the intermediate step and we show that it satisfies the consistency and asymptotic normality conditions. For general spectrally-positive Lévy input a biased estimator is proposed that only uses workload observations above some threshold; the bias can be made arbitrarily small by appropriately choosing the threshold.

This is joint work with Liron Ravner and Onno Boxma. The paper is to appear in *Bernoulli*.

Martingale approach for large queue

Masakiyo Miyazawa
Tokyo University of Science and CHUK, Shenzhen

How do large queues arise in queues and their network? We like to answer to this question through the influence of their arrival processes, service times and service disciplines to the stationary distributions of queue length and waiting times. However, the question is a hard to answer even for a single server queue. So, we study it by asymptotic behaviors of the stationary distribution. We here focus on two different types of asymptotics. One is the tail asymptotics of the stationary distribution, and the other is its scaling limits such as diffusion approximation. In the literature, those asymptotics have been studied in different ways. In this talk, we propose a unified approach based on semimartingale representations of stochastic processes describing queues and their networks. We first exemplify this approach for the workload process in the $GI/G/1$ queue. We then summarize how this approach works for queueing networks.

A part of this work is based on joint work with Anton Braverman and Jim Dai.

Equilibrium adjustment dynamics

Ellen Muir
Stanford University

Assuming traders have an initial endowment of some asset and a commonly known maximum demand, arrive one after another and are privately informed about their values, we derive the efficient market allocation and construct a mechanism that implements it. Under the efficient allocation traders submit orders to a market order book that evolves according to a Markov chain. This setup permits definitions of buyers' and sellers' markets, breadth, depth, thickness, and liquidity of a market that relate only to this order book Markov chain and are thus mechanism-independent. We show that efficiency involves phases of market imbalance during which sellers or buyers are on the long side. This approach also allows us to analyse efficient adjustment dynamics in markets following shocks.

This is joint work with Simon Loertscher.

Convergence of a bivariate flip–flop process

Giang Nguyen
The University of Adelaide

Flip–flop processes refer to a family of stochastic fluid processes which converge to either a standard Brownian motion (SBM) or to a Markov modulated Brownian motion (MMBM). In recent years it has been shown that complex distributional aspects of the univariate SBM and MMBM can be studied through the limiting behaviour of flip–flop processes. In this talk, we define a class of bivariate flip–flop processes whose marginals converge to SBMs and are dependent on each other. We exhibit an example in which the limiting bivariate process is not Gaussian, nonetheless, it possesses desirable qualities, such as being tractable and having a time–varying correlation coefficient function.

This is joint work with Guy Latouche and Oscar Peralta Gutierrez.

Epidemic fadeout

Joshua Ross
The University of Adelaide

Outbreaks of infectious diseases can give rise to a large first wave of cases, followed by a period with a low level of cases, before seeing subsequent waves with dissipating amplitude leading to disease endemicity. In other outbreaks we see only the first wave of infection. Epidemic fadeout refers to this latter scenario, in which infection is eliminated in the trough following the first wave of an outbreak. I will discuss work that has led to a greater understanding of the probability of epidemic fadeout and use of interventions to maximise this probability. This includes results for directly-transmitted and vector-borne disease dynamics.

This is joint work with Peter Ballard, Nigel Bean, and Alun Lloyd.

Accumulating priority queues – A review of recent developments

David Stanford, University of Western Ontario
Ilze Ziedins, University of Auckland

Accumulating priority queues (APQs) permit the priority of customers in a queue to increase with time spent waiting for service, at rates that may vary with the customer class. Their recent development has been primarily motivated by healthcare applications, where under classical priority mechanisms low priority patients might wait for an excessively long time before being treated. This talk will review the developments that have occurred in the past five years, starting with Stanford, Taylor, and Ziedins (2014). We will introduce the concept of accrediting customers and the role of the maximum priority process in determining waiting time distributions, and then discuss extensions of the initial results, including to nonlinear APQs, the optimal choice of the accumulating priority function, a game theoretic version of the problem, and the APQ with initial delays.

Co-authors on this body of work beyond David Stanford, Peter Taylor and Ilze Ziedins include Na Li, Azaz Sharif, Maryam Mojalal, Rick Caron, Blair Bilodeau, Raneetha Abeywickrama, Moshe Haviv, and Binyamin Oz.

Fluid models for transient queueing systems

Gideon Weiss
The University of Haifa

Fluid models are informative for the transient behavior of queueing systems. We survey their use to determine stability of multi-class queueing networks under scheduling, routing and admission control policies, and in particular max pressure policy. Next we survey their use to obtain asymptotically optimal controls. Finally we discuss their role and limitations in describing the behavior of parallel service systems.

Asymptotic behavior of a subcritical fluid model for fair bandwidth sharing with general file size distributions

Ruth J. Williams
University of California, San Diego

This talk concerns the asymptotic behavior of solutions to a subcritical fluid model for a data communication network, where file sizes are generally distributed and the network operates under a fair bandwidth sharing policy. It has been a standing problem to prove stability of the data network model when the offered load is less than capacity. A crucial step in an approach to this problem is to prove stability of subcritical fluid model solutions. Paganini et al. introduced a Lyapunov function for this purpose and gave an argument, assuming that fluid model solutions are sufficiently smooth in time and space that they are strong solutions of a partial differential equation, and assuming that no fluid level on any route touches zero before all route levels reach zero. This talk will show how to prove fluid model stability without such strong assumptions.

This is joint work with Yingjia Fu.

α-classification and β-invariant measures for block-structured Markov chains

Yiqiang Zhao
Carleton University

Motivated by Bean, Bright, Latouche, Pearce, Pollett and Taylor (1977), Bean, Pollett and Taylor (1998, 2000), and by other researchers, in this talk, I will highlight my collaborative work with Q. Li on the spectral analysis, α-classification, and β-invariant measures of Matrices of M/G/1 and GI/M/1 types.

Participants

Azam	Asanjarani	The University of Auckland
Yonit	Barron	Ariel University
Nigel	Bean	The University of Adelaide
Andrew	Black	The University of Adelaide
Zdravko	Botev	University of New South Wales
Rhys	Bowden	The University of Melbourne
Peter	Braunsteins	The University of Queensland
Daryl	Daley	The University of Melbourne
Eleonora	Deiana	Universite de Namur
Sarah	Dendievel	Ghent University
Ton	Dieker	Columbia University
Ali	Eshragh	University of Newcastle
Mark	Fackrell	The University of Melbourne
Jerzy	Filar	The University of Queensland
Jing	Fu	The University of Melbourne
Peter	Glynn	Stanford University
Sophie	Hautphenne	The University of Melbourne
Moshe	Haviv	The Hebrew University of Jerusalem
Qi-Ming	He	University of Waterloo
Marijn	Jansen	The University of Queensland
Stella	Kapodistria	Eindhoven University of Technology
Wathsala	Karunarathne	The University of Melbourne
Paul	Keeler	The University of Melbourne
Offer	Kella	The Hebrew University of Jerusalem
Dirk	Kroese	The University of Queensland
Guy	Latouche	Universite Libre de Bruxelles
Nelly	Litvak	University of Twente and Eindhoven University of Technology
Achini Erandi	Madduma Wellalage	The University of Melbourne
Michel	Mandjes	Universiteit van Amsterdam
Barbara	Margolius	Cleveland State University
Masakiyo	Miyazawa	Tokyo University of Science
Ellen	Muir	Stanford University
Yoni	Nazarathy	The University of Queensland
Giang	Nguyen	The University of Adelaide
Behrooz	Niknami	The University of Melbourne
Malgorzata	O'Reilly	University of Tasmania
Binyamin	Oz	The Hebrew University of Jerusalem
Oscar	Peralta-Gutierrez	The University of Adelaide
Amber	Puha	California State University, San Marcos
Liron	Ravner	University of Amsterdam
Sid	Resnick	Cornell University
Joshua	Ross	The University of Adelaide
Seva	Shneer	Heriot-Watt University
Matthieu	Simon	The University of Melbourne
David	Stanford	University of Western Ontario
Laleh	Tafakori	RMIT
Peter	Taylor	The University of Melbourne
Thomas	Taimre	The University of Queensland
Darryl	Veitch	University of Technology Sydney
Nico	van Dijk	University of Twente
Jiesen	Wang	The University of Melbourne
Gideon	Weiss	University of Haifa
Ruth	Williams	University of California, San Diego
Chenchen	Xing	The University of Melbourne
Hanqin	Zhang	National University of Singapore
Yiqiang	Zhao	Carleton University
Ilze	Ziedins	The University of Auckland