Title: Non-Hamiltonian 4-Regular 3-Connected Planar Graphs with Given Types of Faces

Speaker: Dr. Ong Siew Hui
Institute of Mathematical Sciences

Date: 9 January 2013 (Wednesday)

Time: 3:00 pm – 4:00 pm

Venue: MM3, Institute of Mathematical Sciences

Abstract

In 1965, Tutte proved that every 4-connected planar graph is hamiltonian. An example of a $k$-regular 3-connected planar graph which is non-hamiltonian was constructed by Walther in 1969 for each $k \in \{4, 5\}$.

Let $G_k(n_1, n_2, \ldots, n_t)$ denote the set all $k$-regular 3-connected planar graphs whose faces consist of only $n_i$-gons, $i = 1, 2, \ldots, t$. If $k \in \{4, 5\}$, then it follows from Euler’s formula for plane graphs that $n_1 = 3$.

In 1984, Owens showed that there exist non-hamiltonian members in $G_4(3, m)$ for all integers $m \geq 12$. In particular, he constructed a non-hamiltonian graph in $G_4(3, 12)$ with 600 vertices whose longest cycle contains only 597 vertices. Also, in 1982, Owens constructed a non-hamiltonian member in $G_4(3, 6, 7)$ with only 39 vertices, and a non-hamiltonian member in $G_4(3, 7, 9)$ with only 78 vertices.

We show that (i) there exists a non-hamiltonian member in $G_4(3, m)$ for each $m \in \{7, 8\}$ and (ii) there exists a non-hamiltonian member in $G_4(3, 5 + 3t, 8 + 3t)$ for all integers $t \geq 1$.

SEMUA DIJEMPUT HADIR
Title: Probabilistic Properties and Statistical Inference for a Family of Generalised and Related Distributions

Speaker: Liew Kian Wah (SHB080001)
Institute of Mathematical Sciences

Date: 16 January 2013 (Wednesday)
Time: 3:00 pm – 4:00 pm
Venue: MM3, Institute of Mathematical Sciences

Abstract

Three generalised distributions will be studied from different aspects. The Hurwitz-Lerch zeta (HLZ) distribution that generalises the logarithmic distribution and a class of distributions that follow the power law is considered. To investigate the effects of parameters to the stochastic properties of the HLZ distribution, stochastic orders between members in this large family are established. A relationship between the tail behaviours of the HLZ distribution and that of a class of generalised logarithmic distribution (GLD) is highlighted. The HLZ distribution has shown good flexibilities in empirical modelling. A robust probability generating function (pgf) based estimation method using Hellinger-type divergence is implemented in data-fitting and the results are compared with various other GLD’s. Construction of an augmented pgf is proposed to overcome the difficulties of this estimation procedure when some data are grouped. The Poisson-stopped sum of the Hurwitz-Lerch zeta distribution (Poi-HLZ) is then proposed as a new generalisation of the negative binomial distribution. Several methods have been used in deriving the probability mass function for this new distribution to show the connections among different approaches from mathematics, statistics and actuarial science. Basic statistical measures and probabilistic properties of the Poi-HLZ are examined and the usefulness of the model is demonstrated through examples of data-fitting on some real life datasets. Finally, the inverse trinomial distribution (ITD) is reviewed. Both Poi-HLZ and ITD are proved to be mixed Poisson distribution, which extend the applications of the models for various phenomena. The associated mixing distribution for the ITD is obtained as an infinite Laguerre series and the result is compared to some numerical inversions of Laplace transform.

SEMUA DIJEMPUT HADIR

Research Group: Statistical Modelling and Computing
Title: Semimodules and preservers of traceless symmetric Boolean matrices of factor rank 3

Speaker: Prof. Lim Ming Huat
Institute of Mathematical Sciences

Date: 30 January 2013 (Wednesday)

Time: 3:00 pm – 4:00 pm

Venue: MM3, Institute of Mathematical Sciences

Abstract
Let $\mathcal{B}$ denote the two element Boolean algebra and $Z_n(\mathcal{B})$ be the semimodule of all $n$-square symmetric Boolean matrices with zero diagonal. In this talk we will discuss the structure of (i) subsemimodules of $Z_n(\mathcal{B})$ whose nonzero members all have factor rank 3 where $n \geq 3$, and (ii) linear mappings from $Z_m(\mathcal{O})$ to $Z_n(\mathcal{O})$ that send distinct elements of factor rank 3 to distinct elements of factor rank 3 where $m,n \geq 3$.

SEMUA DIJEMPUT HADIR
Title: Near-exact distributions for the product of Beta random variables

Speaker: Prof. Carlos A. Coelho

Mathematics Department and Center for Mathematics and its Applications (CMA), Faculdade de Ciências e Tecnologia Universidade Nova de Lisboa, Portugal.

Date: 4 February 2013 (Monday)

Time: 3:00 pm – 4:00 pm

Venue: MM3, Institute of Mathematical Sciences

Abstract

Many likelihood ratio test statistics used in Multivariate Analysis, as well as other statistics, have the same distribution as that of the product of independent Beta random variables. Hence the importance of this distribution. However, obtaining very well-performing and manageable approximations for this distribution has been a long standing challenge, which many authors have addressed. In a joint work with Rui P. Alberto, the author takes a first approach, based on recently obtained asymptotic expansions of ratios of gamma functions, which enables the obtention of the distribution of this product in a much manageable form. However, for the general case, this approach leads to a form which although being much manageable and in line with some previous results, suffers from serious problems of precision and convergence, which in most cases prevent its practical use. But, based on these first results that the authors, using the concept of near-exact distribution, are able to obtain highly manageable but extremely accurate approximations for all cases of the distribution of the product of independent beta random variables. These near-exact approximations may be applied to the distribution of many likelihood ratio test statistics used in Multivariate Analysis and, given their high manageability, accuracy and proximity to the exact distribution, may in practice be used instead of the exact distribution. Several examples are given.

SEMUA DIJEMPUT HADIR

Research Group: Statistics
Title: A Study on Sufficient Conditions and Numerical Solution of Oscillatory Nonlinear Ordinary Differential Equations of Second and Third Order

Speaker: MASTORA JABER SAAD
PhD Candidate, Institute of Mathematical Sciences
University of Malaya

Date: 06 Feb 2013 (Wednesday)

Time: 3:00 pm – 4:00 pm

Venue: MM3, Institute of Mathematical Sciences

Abstract

This study deals with the problem of oscillation of the solution of the second and third order nonlinear ordinary differential equations of the form

\[(r(t)x(t))' + q(t)\Phi(g(x(t)),r(t)x(t)) = H(t,x(t))\] \hspace{1cm} (1)

\[(r(t)\Psi'(x(t))x(t))' + h(t)x(t) + q(t)\Phi(g(x(t)),r(t)\Psi'(x(t))x(t)) = H(t,x(t),x(t))\] \hspace{1cm} (2)

\[(r(t)f'(x(t)))' + q(t)g'(x(t)) = H(t,x(t),x(t),x(t))\] \hspace{1cm} (3)

The oscillatory behavior of solution of the ordinary differential equations (1), (2) and (3) are studied to obtain sufficient conditions for oscillation of equations (1), (2) and (3). The obtained results improve and extend some existing results in the literature. Some examples are given with numerical solutions which are computed using Runge Kutta method of fourth order (RK4) to illustrate the results.
Title: Haar Operational Matrix Method for Solving Continuous Optimal Control Problems

Speaker: WALEEDA SWAIDAN ALI
    PhD Candidate, Institute of Mathematical Sciences
    University of Malaya

Date: 08 Feb 2013 (Friday)
Time: 3:00 pm – 4:00 pm
Venue: MM3, Institute of Mathematical Sciences

Abstract

Optimal control is an important branch of mathematics and the applications for it can be found in engineering, science and economics. Although the necessary and sufficient conditions for optimality have already been derived, they are only useful for finding analytical solutions for quite restricted cases. If we assume full-state knowledge and if the optimal control problem is a linear quadratic then the optimal control is a linear feedback of the state, obtained by solving a matrix Riccati equation. However if the system is nonlinear then the optimal control is a state feedback function depend on the solution to the Hamilton-Jacobi Bellman equation, which is very difficult to solve analytically. In this talk we present a simple numerical technique based on a combination of Haar wavelet collocation method and successive General Hamilton-Jacobi-Bellman equation to solve the nonlinear optimal control problem.

SEMAU DIJEMPAT HADIR

Research Group: Algebraic and Analytic Methods in Mathematical Sciences
Title: Applications of Erlang Mixtures in Actuarial Science

Speaker: Professor Sheldon Lin
Department of Statistics (University of Toronto)

Date: 20 February 2013 (Wednesday)
Time: 3:00 pm – 4:00 pm
Venue: MM3, Institute of Mathematical Sciences

Abstract

In this talk I will discuss analytical and computational properties of univariate and multivariate Erlang mixtures and the applications of these mixtures in actuarial science. The first half of the talk will focus on the class of univariate Erlang mixtures. I will show that the class is larger than it appears. I will next propose an EM algorithm for estimation of finite Erlang mixtures. Performance of the algorithm is tested using simulated and real insurance data. Distributional and moment properties are then discussed in the context of insurance risk analysis.

In the second half of the talk I will introduce a class of multivariate Erlang mixtures each of which is conditionally independent. I would argue that such a multivariate Erlang mixture could be an ideal parametric model for modeling multivariate risks in insurance, especially when modeling dependence is a concern, as the class is dense in the space of positive continuous multivariate distributions and an EM algorithm, similar to the univariate case, for estimation is available. I will also show that many quantities of interest such as the joint density and distribution function, the Laplace transform, moments, and Kendall's tau have a closed form. Further, the sum of the component random variables is a univariate Erlang mixture, which enables us to model aggregated risks in a straightforward way. Finally I will introduce a new notion called quasi-cocomonotonicity that can be useful to identify upper and lower bounds in a multivariate stochastic order and to construct a multivariate dependence model.

SEMUA DIJEMPUT HADIR
Title: Probability Distributions for Axial Data

Speaker: Prof. Kunio Shimizu
Department of Mathematics, Faculty of Science and Technology, Keio University.

Date: 20 March 2013 (Wednesday)
Time: 3:00 pm – 4:00 pm
Venue: MM3, Institute of Mathematical Sciences

Abstract
SEMUA DIJEMPUT HADIR

An axis is an undirected line where there is no reason to distinguish one end of the line from the other (Fisher, 1993). In Fisher’s book some examples of such phenomena are introduced: a fracture in a rock exposure, face-cleat in a coal seam, long-axis orientations of feldspar laths in basalt, horizontal axes of outwash pebbles and orientations of rock cores.

If axial observations are multiplied by 2, circular models might be used to fit to the changed data. However, Arnold and SenGupta (2006, 2011) discussed wrapping of a circular distribution as a method for constructing axial distributions. The axial von Mises distribution is obtained as a special case of the wrapping method. In the talk the following topics (Abe et al., 2012) are presented: (1) a method of trigonometric moments for the axial von Mises distribution as an alternative of the moment-method by Arnold and SenGupta (2006), (2) sine-skewed axial Jones-Pewsey; Pewsey, von Mises and wrapped Cauchy distributions as special cases of a more general construction of skew axial distributions, and (3) the orientations of logs on the floor of a primeval spruce forest as an example.
Title: Various Mixed Poisson Distributions with Applications on Insurance Claim Data

Speaker: SOMAYEH NIK MANESH
PhD student, Institute of Mathematical Sciences, University of Malaya

Date: 27 March 2013 (Wednesday)
Time: 3:00 pm – 4:00 pm
Venue: MM3, Institute of Mathematical Sciences

Abstract

The Poisson distribution can be considered as a standard distribution for modeling count data. In the case of modeling count data, the mixed Poisson distributions have been considered as a more flexible alternative than the Poisson. Many attempts have been implemented to expand the classes of the mixed distributions, especially for the distributions of the exponential family, resulting in a better fit for count data. In the case of modeling count data, the Poisson, the negative binomial, the Poisson-inverse Gaussian, the Poisson-lognormal, the Poisson-Lindley and the generalized Poisson models have been proposed and applied.

Our contributions on these issues include proposing a new mixed Poisson distribution which is obtained by mixing the distributions of the Poisson and generalized Lindley (GL) distribution. Also the properties of P-GL and its parameter estimations by maximum likelihood (ML) and methods of moments are presented.

Motivated by the work of GL distributions, the P-GL which has the flexibility to model overdispersed data is further researched here.

In several cases, count data often have excessive number of zero outcomes than are expected in the Poisson. In motor insurance as an example, claim counts usually include a relatively large number of zeros or a situation of no insurance claim, where deductibles and no claim discounts may increase the proportion of zeros since small claims are not reported by insured drivers.

In terms of performance, the proposed distribution is fitted to sets of insurance data and compared to other commonly used discrete distributions. In this research we also introduce new model by mixing Poisson distribution and weighted Lindley distribution which is appropriate for modeling insurance claim data. Also this research examines various properties of this new distribution and provides numerical examples to show the flexibility of the model.

We use statistical softwares to built-in functions for fitting the P-GL and the P-WL models both in simulated data as well as real data sets. Our simulation results shows that these new mixed Poisson distributions can be more appropriate model.

Finally we also derive a multivariate version of the P-GL distribution. This new class of distribution can be used for modeling multivariate dependent count data when marginal overdispersion is present. Our finding suggests the distributions of P-GL and P-WL are better choice for modeling count data.

SEMUA DIJEMPUT HADIR
INSTITUT SAINS MATEMATIK
UNIVERSITI MALAYA

SIRI SEMINAR KUMPULAN PENYELIDIKAN

Title: Prediction via L-statistics in multivariate elliptical distributions

Speaker: Dr. Ahad Jamalizadeh
Shahid Bahonar University, Kerman, Iran

Date: 20 March 2013 (Wednesday)
Time: 4:00 pm – 5:00 pm
Venue: MM3, Institute of Mathematical Sciences

Abstract
We consider random vectors $X_{K\times 1}$ and $Y_{N\times 1}$ having a multivariate elliptical joint distribution, and derive the exact joint distribution of $X$ and $L$-statistics from $Y$, as a mixture of multivariate unified skew-elliptical distributions. This mixture representation enables us to predict $X$ based on $L$-statistics from $Y$, and vice versa, when $K=1$ and with normal and t-distributions. Our results extend and generalize previous ones in two ways: first, we consider a general multivariate set-up for which $K \geq 1$ and $N \geq 2$, and second, we adopt the multivariate elliptical distribution to include previous multivariate normal and t-formulations as special cases. We illustrate our results using data on student test scores.

SEMUA DIJEMPUT HADIR
Title: Skew-elliptical distributions and their relationship with order statistics

Speaker: Dr. Ahad Jamalizadeh
Shahid Bahonar University, Kerman, Iran

Date: 27 March 2013 (Wednesday)
Time: 4:00 pm – 5:00 pm
Venue: MM3, Institute of Mathematical Sciences

Abstract

In this talk, I will discuss some recent work of mine on skew-elliptical distributions and their relationship with order statistics from multivariate elliptical and multivariate unified skew-elliptical distributions. The first part of my talk will discuss distributions of order statistics from a bivariate normal distribution. We show that these distributions are mixtures of the univariate Azzalini skew-normal distributions (Azzalini, 1985). Followed by this, I will discuss our work on distributions of order statistics from a trivariate normal distribution and we will present explicit expressions for mean and variance of these order statistics. The next part of my talk will discuss an extension of this work where we will discuss order statistics from multivariate elliptical distributions and we look at the normal and t cases in details. The last part of my talk involves our recent submitted work where we show that the cumulative distribution functions (cdfs) of order statistics and linear combinations of order statistics from multivariate skew-elliptical distributions can be expressed as mixtures of cdfs of multivariate unified skew-elliptical distributions. These mixture representations can be used to obtain moment generating functions and moments of order statistics and linear combinations of order statistics, where they exist.

SEMUA DIJEMPUT HADIR

Research group: Centre for Mathematical and Statistical Modelling
INSTITUT SAINS MATEMATIK
UNIVERSITI MALAYA

SIRI SEMINAR KUMPULAN PENYELIDIKAN

Title: Warped product CR-submanifolds of Lorentzian $\beta$-Kenmotsu manifolds

Speaker: Dr. Siraj Uddin
ISM, University of Malaya

Date: 3 April 2013 (Wednesday)
Time: 3:00 pm – 4:00 pm
Venue: MM3, Institute of Mathematical Sciences

Abstract
In this talk we will discuss the existence and non-existence of warped products. In case of existence, we will discuss some geometric properties of warped product submanifolds of Lorentzian $\beta$-Kenmotsu manifolds. Finally, we obtain a characterization result for CR-warped products.

SEMUA DIJEMPUT HADIR
INSTITUT SAINS MATHEMATIK
UNIVERSITI MALAYA

SIRI SEMINAR KUMPULAN PENYELIDIKAN

Title : On Self-Complementary Magic Squares
Speaker : Prof. Chia Gek Ling
           Institut Sains Matematik (University of Malaya)
Date : 24 April 2013 (Wednesday)
Time : 3:00 pm – 4:00 pm
Venue : MM3, Institute of Mathematical Sciences

Abstract

SEMUA DIJEMPUT HADIR

A magic square of order n is an n x n array of integers from 1, 2, …, n^2 so that the sum of the integers in each row, column and the diagonal is the same number. Two magic squares are said to be equivalent if one can be obtained from the other by rotation or reflection. If every entry x of a magic square M of order n is replaced by n^2+1-x then we obtain the complement of M (which is also a magic square of order n). A magic square is said to be self-complementary if it is equivalent to its complement. In this talk, some structural properties on self-complementary magic squares as well as some methods of constructing such squares will be presented.
Title: Hellinger Type Distance using Probability Generating Functions in Parameter Estimation for Multivariate Discrete Distributions

Speaker: Dr. Ng Choung Min
Institute of Mathematical Sciences
University Malaya

Date: 8 May 2013 (Wednesday)
Time: 3:00 pm – 4:00 pm
Venue: MM3, Institute of Mathematical Sciences

Abstract

SEMUA DIJEMPUT HADIR

Alternative robust parameter estimation methods such as the minimum Hellinger distance (MHD) estimation have been proposed in the literature since the well-known maximum likelihood (ML) estimation may be sensitive to the presence of outliers. However, in the bivariate and multivariate case, the MHD as well as the ML method leads to computer intensive estimation especially when the joint probability function is complicated. In this paper, a Hellinger type distance measure based on the probability generating function is proposed as a tool for rapid parameter estimation for multivariate discrete distributions that is also less sensitive to outliers. The proposed method yields consistent estimators and is computationally much faster than the ML or MHD estimation. Simulated and real data sets have been used to investigate the proposed estimation method.

Research Group: Statistics
INSTITUT SAINS MATEMATIK
UNIVERSITI MALAYA

SIRI SEMINAR KUMPULAN PENYELIDIKAN

Title : Stability Analysis of Discrete-time Fuzzy Systems and Applications

Speaker : Prof. Dr. P. BALASUBRAMANIAM
           Department of Mathematics
           Gandhigram Rural Institute - Deemed University
           Gandhigram - 624 302
           Tamil Nadu, India.

Date  : 15 May 2013 (Wednesday)
Time  : 3.00 PM – 4.00 PM
Venue : MM3, Institute of Mathematical Sciences

ABSTRACT
SEMUA DIJEMPPUT HADIR

Discrete-time systems are usually modeled by difference equations. The properties of discrete-time systems are basically the same as they are for continuous-time systems. Many mathematical models for real-world phenomena are inherently nonlinear, and the issues of stability analysis are usually very important but the derivations are very hard. In this presentation, fuzzy logic theory could be demonstrated for the effective dealing with a variety of complex nonlinear systems. Among various fuzzy systems, one of the most popular Takagi-Sugeno (T-S) model is going be demonstrated with applications.
In this presentation, importance of bifurcation of dynamical systems could be highlighted. The local stability of some one and two dimensional functional equations is given. A spatial dependence of functional equations is introduced and the stability of its homogeneous equilibrium is studied. A numerical example for Hopf-type bifurcation of population model and its stochastic dynamical system is going to be demonstrated.
Title : Estimating function for random coefficient models with correlated errors

Speaker: Dr. Ibrahim Mohamed
Institut Sains Matematik, Universiti Malaya

Date : 29 May 2013 (Wednesday)
Time : 3:00 pm – 4:00 pm
Venue : MM3, Institute of Mathematical Sciences

Abstract

We consider the random coefficient autoregressive (RCA) models, one of the classes of non-linear time series models, to accommodate some non-linear characteristic in the data by introducing a random term in the model. While most RCA modelling assumes that the random term and the error are independent, fewer works can be found when they are dependent. We will use the quadratic estimating functions approach to jointly estimate the parameter of the model, mainly, the model coefficient, the variance of the random term and the correlation between random term and the error. We then extend the approach to the case of RCA model with GARCH innovation.

SEMUA DIJEMPUT HADIR
Title: Nonparametric Hazard Regression for State Waiting Times in a Multistate Model

Speaker: Prof. Somnath Datta  
Department of Bioinformatics & Biostatistics,  
School of Public Health and Information Sciences  
University of Louisville (USA)

Date: 24 June 2013 (Monday)  
Time: 10:00 am – 11:00 am  
Venue: MM3, Institute of Mathematical Sciences

Abstract

Traditional methods for the analysis of failure time data are often employed in the marginal analysis of waiting times from multistate models. However, such methods can exhibit substantial bias when transition times between model states are dependent, even when censoring is independent. We introduce a nonparametric, inverse probability of censoring weighted (IPCW) linear hazard model for waiting times from multistate models, analogous to Aalen's linear hazard model for failure time data. We provide a weak convergence result for the IPCW regression coefficient estimator and illustrate its unbiasedness through a simulation study, while also demonstrating the bias of the traditional linear hazard model for failure time data when waiting times are correlated. The IPCW estimators are used to examine prognostic indicators for patients receiving bone marrow transplant and predictors of ambulatory recovery in a data set of incomplete spinal cord injury patients receiving activity-based rehabilitation.
Title: Surrogate variable analysis using partial least squares (SVA-PLS) in gene expression studies

Speaker: Prof. Susmita Datta  
Department of Bioinformatics & Biostatistics,  
School of Public Health and Information Sciences  
University of Louisville (USA)

Date: 24 June 2013 (Monday)

Time: 11:00 am – 12:00 noon

Venue: MM3, Institute of Mathematical Sciences

Abstract

In a typical gene expression profiling study, our prime objective is to identify the genes that are differentially expressed between the samples from two different tissue types. Commonly, standard analysis of variance (ANOVA)/regression is implemented to identify the relative effects of these genes over the two types of samples from their respective arrays of expression levels. But, this technique becomes fundamentally flawed when there are unaccounted sources of variability in these arrays (latent variables attributable to different biological, environmental or other factors relevant in the context). These factors distort the true picture of differential gene expression between the two tissue types and introduce spurious signals of expression heterogeneity. As a result, many genes which are actually differentially expressed are not detected, whereas many others are falsely identified as positives. Moreover, these distortions can be different for different genes. Thus, it is also not possible to get rid of these variations by simple array normalizations. This both-way error can lead to a serious loss in sensitivity and specificity, thereby causing a severe inefficiency in the underlying multiple testing problem. In this work, we attempt to identify the hidden effects of the underlying latent factors in a gene expression profiling study by partial least squares (PLS) and apply ANCOVA technique with the PLS-identified signatures of these hidden effects as covariates, in order to identify the genes that are truly differentially expressed between the two concerned tissue types. We compare the performance of our method SVA-PLS with standard ANOVA and a relatively recent technique of surrogate variable analysis (SVA), on a wide variety of simulation settings (incorporating different effects of the hidden variable, under situations with varying signal intensities and gene groupings). In all settings, our method yields the highest sensitivity while maintaining relatively reasonable values for the specificity, false discovery rate and false non-discovery rate. Application of our method to gene expression profiling for acute megakaryoblastic leukemia shows that our method detects an additional six genes, that are missed by both the standard ANOVA method as well as SVA, but may be relevant to this disease, as can be seen from mining the existing literature.

Research Group: Centre for Mathematical and Statistical Modelling
Ong and Mukerjee (2011) developed two-sided Bayesian tolerance intervals, with approximate frequentist validity, for a future observation in balanced one-way and two-way nested random effects models using probability matching priors (PMP). On the other hand Krishnamoorthy and Lian (2012) examined closed-form approximate tolerance intervals by the modified large sample (MLS) approach. The first part of this work consists of a comparative study via Monte Carlo simulation methods to examine the performances of these two approaches for normal and non-normal error distributions. In the second part, we derive asymptotic results leading to explicit formulae for two-sided Bayesian and frequentist tolerance intervals in a general framework of parametric models. Simulation studies are conducted to evaluate the performance of the asymptotic results in finite samples.
Title: Dependency Analysis using Dimension Reduction for Statistical Network Analysis

Speaker: Prof. Dr. Ashis SenGupta
Applied Statistics Unit, Indian Statistical Institute
Kolkata, India

Date: 14 June 2013 (Friday)
Time: 11:00 am – 12:00 pm
Venue: DKM4, Institute of Mathematical Sciences

Abstract

Often the random vector variable, X, being encountered, in network analysis, be it say with social, biological or environmental characteristics, is invariably not only of a large dimension but also with significant dependence between its components. But, it often also admits of meaningful grouping(s) into two or more mutually exclusive and exhaustive subvectors. Dimension reduction techniques are then sought to obtain “representative” new variables for each group to be formed by taking suitable compounds of the components within that group. This resulted in the substantially reduced dimensional vector variable Y to represent X. This also greatly facilitates the associated computational and inferential statistical analyses. Hotelling’s construction of canonical variables for the case of two groups of quantitative variables has been generalized in various directions to yield Generalized Canonical Variables (GCVs) that encompass more than two groups, both quantitative and qualitative components in X. The availability of packages makes the implementation of such techniques for real-life problems quite feasible and attractive. On the inferential side, a variety of new types of hypotheses is posed: determination of optimal number of groups, best grouping for the same number of groups, and so on. While the corresponding distribution theory is quite involved, some interesting results are, nevertheless, emerging also. Further, in several networks, constraints or orderings on the weights naturally appear, leading to the need for constrained versions of the GCVs. Further, non-linear compounding functions or non-normal underlying population distributions need to be considered for inference purposes. Some solutions and many challenges will be exposed in the talk. These topics constitute a fertile area and are in need of further theoretical and applied research, which should be very useful to a wide variety of practitioners of statistical network analysis.

Research Group: Centre for Mathematical and Statistical Modelling
Title: Applications of fractional order nonlinear problems and a new method for synchronization of fractional order chaotic systems

Speaker: Dr. Subir Das  
Department of Applied Mathematics  
Indian Institute of Technology (BHU), Varanasi – 221 005, India

Date: 10 July 2013 (Wednesday)  
Time: 10:00 - 11:00 am  
Venue: MM3, Institute of Mathematical Sciences

Abstract

During the seminar presentation, three important applications of fractional order derivatives in engineering problems will be discussed.

(a) A mathematical model of nonlinear reaction diffusion equation with fractional time derivative in the form of a rapidly convergent series with easily computable components. Fractional reaction diffusion equation is used for modeling of merging travel solutions in nonlinear system for popular dynamics. The fractional derivatives are described in the Caputo sense. The anomalous behaviors of the nonlinear problems in the form of sub- and super-diffusion due to the presence of reaction term will be shown graphically for different particular cases.

(b) The approximate solutions of the non-linear Swift-Hohenberg equation with fractional order time derivative in the presence of dispersive term will be shown. Time fractional nonlinear partial differential equation with the presence of dispersion which predicts hydrodynamic fluctuations at convective instability will be discussed.

(c) A modified adaptive control method is developed and the parameters identification method is then applied in fractional order systems with unknown parameters. The new modified control method based on Lyapunov stability theory is successfully applied to investigate the synchronization of pair of fractional order systems amongst Genesio–Tesi, Qi and Chen systems. By means of the Adams–Bosford–Moulton method, the numerical results show that the modified method is easy to implement and reliable for synchronizing the two different fractional order chaotic systems.

Research Group: Centre for Mathematical and Statistical Modelling
Title: Unification and Generalization of Non-Central Negative Binomial, Charlier Series Distributions and their Extensions

Speaker: Dr. Subrata Chakraborty,
Department of Statistics,
Dibrugarh University, Dibrugrah-786004,
Assam, India
E-mail address: subrata_arya@yahoo.co.in

Date: 24 July 2013 (Wednesday)
Time: 3.00 pm – 4.00 pm
Venue: MM3, Institute of Mathematical Sciences

Abstract
New formulations of the non-central negative binomial distribution (NNBD) and the Charlier series distribution (CSD) and their recent extensions are considered. Two generalizations, one of which unifies the NNBD and CSD and the other unifies the Generalized CSD (GCSD) and Extended NNBD (ENNBD) are proposed. Derivation of some new NNBD, CSD, and their extensions are also considered. Some formulations of the proposed new distributions are discussed. Moments, index of dispersion are derived. Parameter estimation and examples of data fitting is presented.

Research Group: Centre for Mathematical and Statistical Modelling
Abstract

The preserver problems concern the characterisation of mappings between matrix spaces that leave certain invariants, such as functions, subsets and relations. The first paper on preserver problems can be found in Frobenius’ work in 1897. Let \( F \) be a field. Let \( V \) denote either the vector space of all rectangular matrices over \( F \) with at least three elements, the vector space of all Hermitian matrices over \( F \) with characteristic not two associated with an involution, or the vector space of all alternate matrices over \( F \) with at least three elements. In this talk, we will present the characterisation of surjective mappings \( T \) from \( V \) onto itself such that for every pair \( A, B \in V \), \( \text{rank} \ (A - B) \leq k \) if and only if \( \text{rank} \ (T(A) - T(B)) \leq k \) for some integer \( k \), \( 1 < k < n \), where \( n \) denotes the maximal rank of matrices in the space. Some other results on preserver problems will also be discussed.
The rank of a graph is defined to be the rank of its adjacency matrix. A graph is called reduced if it has no isolated vertices and no two vertices with the same set of neighbours. Determining the order of a reduced graph with a given rank is an important problem and has a connection with the communication complexity problem. In this regard, Akbari, Cameron, and Khosrovshahi conjectured that the number of vertices of every reduced graph of rank $r$ is at most $m(r) = 2^{(r+2)/2} - 2$ if $r$ is even and $m(r) = 5 \cdot 2^{(r-3)/2} - 2$ if $r$ is odd. We prove that if the conjecture is not true, then there would be a counterexample of rank at most 46. We also show that every reduced graph of rank $r$ has at most $8m(r)+14$ vertices. This is a joint work with A. Mohammadian and B. Tayfeh-Rezaie.
Title: Seidel eigenvalues of a graph and Haemer's conjecture

Speaker: Ebrahim Ghorbani
Department of Mathematics, K.N. Toosi University of Technology, Tehran, Iran
School of Mathematics, Institute for Research in Fundamental Sciences (IPM), Tehran, Iran

Date: 28 August 2013 (Wednesday)
Time: 3:00 pm – 4:00 pm
Venue: MM3, Institut Sains Matematik

Abstrak
Let G be a simple graph with vertex set \{v_1, \ldots, v_n\}. The Seidel matrix of G is an nxn matrix S(G) = (s_{ij}) with zeros on the diagonal and for i \neq j, s_{ij} is -1 if v_i and v_j are adjacent, and is 1 otherwise. Let \theta_1(G), \ldots, \theta_n(G) be the eigenvalues of S(G). The Seidel energy of G is defined as |\theta_1(G)| + \ldots + |\theta_n(G)|. Willem Haemers conjectured that the Seidel energy of any graph with n vertices is at least 2n - 2, the Seidel energy of the complete graph with n vertices. In this talk, I review basic properties of Seidel matrix of a graph and then discuss the following result motivated by the Haemers' conjecture:

for any \alpha with 0 < \alpha < 2, \ |\theta_1(G)|^\alpha + \ldots + |\theta_n(G)|^\alpha \geq (n - 1)^\alpha + n - 1 if and only if |\text{det}(S(G))| \geq n - 1.

This, in particular, implies the Haemers' conjecture for all graphs G with |\text{det}(S(G))| \geq n - 1.
Title: Bayesian nonlinear regression for the air pollution effects on daily clinic visits in small areas of Taiwan

Speaker: Dr. Atanu Biswas (atanu@isical.ac.in)
Indian Statistical Institute, Kolkata

Date: 4 September 2013 (Wednesday)

Time: 3:00 – 4:00 pm

Venue: MM3, Institute of Mathematical Sciences

Abstract

We consider the complete clinic visit records and environmental monitoring data at 50 townships and city districts where ambient air monitoring stations of Taiwan Air Quality Monitoring Stations are located. A Bayesian analysis is carried out using regression spline model. The appropriate model is selected using Bayesian model averaging. A brief account of our results are provided for the elderly patients group.
The skewness of a graph G is the minimum number of edges in G whose deletion results in a planar graph. Hence the skewness of a graph could be regarded as a measure on how non-planar a graph could be. The skewness of a graph is clearly a lower bound of its crossing number. We prove some results concerning the skewness for the join of two graphs. We then use these results to determine completely the skewness of complete k-partite graphs for k = 2, 3, 4.
Title: A systematic graduation technique applicable to mortality and other data series

Speaker: Dr. Boualem Djehiche

Date: 11 September 2013 (Wednesday)

Time: 3:00 – 4:00 pm

Venue: MM3, Institute of Mathematical Sciences

Abstract

I will review some recent results on graduation technique devised by Leser for insurance data and by Hodrick and Prescott for financial data. The technique is also extended to time series taking values in an arbitrary separable Hilbert space. This topic does not need heavy tools to grasp and it covers ideas inverse problems in infinite dimensional spaces.
Title: Graphs with Given Cyclomatic Numbers having Hamilton-Connected Square

Speaker: Prof. Chia Gek Ling  
Institut Sains Matematik (University Malaya)

Date: 25 September 2013 (Wednesday)

Time: 3:00 pm – 4:00 pm

Venue: MM3, Institute of Mathematical Sciences

Abstract

SEMUA DIJEMPUT HADIR

The square of a graph $G$ is the graph obtained from $G$ by adding edges joining those pairs of vertices whose distance from each other in $G$ is two. If $G$ is connected, then the cyclomatic number of $G$ is defined as $|E(G)| \cdot |V(G)| + 1$. Graphs with cyclomatic number no more than one whose square are Hamilton-connected have been characterized, among other things, in [Discrete Math. 309 (2009) 4608--4613]. This talk presents an account of some recent works done with W. Hemakul and S. Singhun concerning graphs with cyclomatic numbers two and three whose square are Hamilton-connected.
Title: Asymptotic properties of maximum likelihood and moment estimators in a new discrete distribution

Speaker: Dr. G. Nanjundan
Department of Statistics Bangalore University (India)

Date: 10 October 2013 (Thursday)

Time: 10:00 – 11:00 am

Venue: MM3, Institute of Mathematical Sciences

Abstract

Sreehari (2009) has characterized a class of discrete distributions analogous to Burr distribution. One among them has the probability mass function

\[ p(x) = (x + 1 - \theta) \frac{\theta^x}{(x + 1)!}, \quad x = 0, 1, 2, \ldots, 0 < \theta < 1. \]

The maximum likelihood and the moment estimators of the parameter \( \theta \) in the above distribution and its truncated version are derived. Further, the asymptotic normality of these estimators in the case of both the distributions are discussed.
Title: Certain generalizations of Einstein manifolds

Speaker: Prof. U. C. De
Department of Pure Mathematics, University of Calcutta, Kolkata, India

Date: 20 November 2013 (Wednesday)
Time: 3:00 pm – 4:00 pm
Venue: MM3, Institute of Mathematical Sciences

Abstract

A Riemannian or semi-Riemannian manifold \((M^2, g)\), \(\text{dim} M = n \geq 2\), is said to be an Einstein manifold if the following condition
\[ S = \frac{r}{n} g \]
holds on \(M\), where \(S\) and \(r\) denote the Ricci tensor and scalar curvature of \((M^2, g)\) respectively. Einstein manifolds play an important role in Riemannian Geometry, as well as in general theory of relativity.

More generally, \((M^2, g)\), is called a quasi-Einstein manifold if at every point \(x \in M\), its Ricci tensor satisfies the condition \(S = ag + bA \otimes A\), where \(a, b \in \mathbb{R}\) and \(A\) is a non-zero 1-form. Quasi-Einstein manifolds arose during the study of exact solutions of the Einstein field equations as well as during consideration of quasi-umbilical hypersurfaces of conformally at spaces. Quasi-Einstein manifold have been studied by several authors.

In the present talk we discuss some geometric properties and examples of quasi-Einstein manifolds. Also some applications have been mentioned. Next we introduce some generalizations of quasi-Einstein manifolds. The existence of these generalizations has been proved by suitable examples.
Title: On trans-Sasakian manifolds

Speaker: Prof. U. C. De  
Department of Pure Mathematics, University of Calcutta, Kolkata, India

Date: 22 November 2013 (Friday)

Time: 3:00 pm – 4:00 pm

Venue: MM3, Institute of Mathematical Sciences

Abstract

In the Gray-Hervella classification of almost Hermitian manifolds there appears a class, $W_4$ of Hermitian manifold which are closely related to locally conformal Kaehler manifolds [Ann. Mat. Pure Appl. 1980]. An almost contact metric structure $(\phi, \xi, \eta, g)$ on a manifold $M$ is called a trans-Sasakian structure if $(M \times \mathbb{R}, J, G)$ belongs to the class $W_4$, where $J$ is the almost complex structure on $M \times \mathbb{R}$ defined by

$$J\left(X, f \frac{d}{dt}\right) = (\phi X - f\xi, \eta(X) \frac{d}{dt})$$

for all vector fields $X$ on $M$ and smooth function $f$ on $M \times \mathbb{R}$ and $G$ is the product metric on $M \times \mathbb{R}$. This may be expressed by the condition

$$(\nabla_X \phi)Y = a(g(X, Y)\xi - \eta(Y)X) + \beta(g(\phi X, Y)\xi - \eta(Y)\phi X)$$

where $a$ and $\beta$ are smooth functions and we say that the trans-Sasakian structure is of type $(a, \beta)$. Trans-Sasakian structure of type $(0; 0), (0; \beta)$ and $(a; 0)$ are cosymplectic, $\beta$-Kenmotsu and $a$-Sasakian respectively provided $a, \beta \in \mathbb{R}$.

J. C. Marrero in 1992 proved that trans-Sasakian manifold of dim $\geq 5$ is either cosymplectic or $a$-Sasakian or $\beta$-Kenmotsu manifolds.

On the other hand, 3-dimensional proper trans-Sasakian manifolds are constructed by Marrero. However the Ricci operator, Ricci curvature and curvature tensor for 3-dimensional trans-Sasakian manifolds are not discussed so far. In our paper [Kyungpook Math. Journal, 2003] we find out the explicit formulae of Ricci operator, Ricci tensor and curvature tensor. In the present talk we discuss some geometric properties of 3-dimensional trans-Sasakian manifolds. Among others it is proved that if a 3-dimensional compact, connected trans-Sasakian manifold is of constant curvature, then it is either $a$-Sasakian or $\beta$-Kenmotsu. We give examples of proper 3-dimensional trans-Sasakian manifolds. Finally, we study Ricci solitons in 3-dimensional trans-Sasakian manifolds.

SEMUA DIJEMPUT HADIR
Title: On almost pseudo conformally symmetric manifolds with applications to relativity

Speaker: Prof. U. C. De
Department of Pure Mathematics, University of Calcutta, Kolkata, India

Date: 27 November 2013 (Wednesday)
Time: 3:00 pm – 4:00 pm
Venue: MM3, Institute of Mathematical Sciences

Abstract

In 1987 M. C. Chaki introduced the notion of pseudo symmetric manifolds. This notion is different from the Deszesz’s notion of pseudosymmetry. Since then several authors have studied such a manifold and generalize such a structure. In 2008, U. C. De and A. K. Gazi introduced the notion of almost pseudosymmetric manifolds. In the present talk we have shown that a conformal deformation of every conformally recurrent metric gives rise to a new type of Riemannian manifold which is called almost pseudo conformally symmetric manifold. The notion generalizes the notion of conformally quasi-recurrent manifolds by M. Prvanovic in 1988. Some interesting geometric properties have been obtained. The existence of such a manifold is also proved by an example. Next we consider almost pseudo conformally symmetric Ricci-recurrent manifolds. Finally, we obtain some results in an almost pseudo conformally symmetric Ricci-recurrent spacetime.
Title: Construction of Highly Efficient Factorial Designs for cDNA Microarray Experiments (A General Method)

Speaker: Professor Rahul Mukerjee
Indian Institute of Management Calcutta,
Joka, Diamond Harbour Road,
Kolkata 700 104, India

Date: Wednesday 4 December 2013
Time: 3:00-4:00 pm
Venue: MM3, Institute of Mathematical Sciences

Abstract
(joint work with Runchu Zhang)

A general method for obtaining highly efficient factorial designs of relatively small sizes is developed for cDNA microarray experiments. It allows the main effects and interactions to be of possibly unequal importance. First, the approximate theory is employed to get an optimal design measure which is then discretized. It is, however, observed that a naïve discretization may fail to yield an exact design of the stipulated size and, even when it yields such an exact design, there is often scope for improvement in efficiency. To address these issues, we propose a step-up/down procedure which is seen to work very well. The resulting designs turn out to be quite robust to possible dye-color effects and heteroscedasticity. We focus on the baseline and all-to-next parameterizations but our method works equally well also for hybrids of the two and other parameterizations.

SEMUA DIJEMPUT HADIR
Title: Analogies between Electromagnetism and Gravitation in General Relativity

Speaker: Prof. Zafar Ahsan
Department of Mathematics, Aligarh Muslim, Aligarh, India

Date: Friday 6 December 2013
Time: 3:00-4:00 pm
Venue: MM3, Institute of Mathematical Sciences

Abstract
The correspondence between electromagnetism and gravitation is very rich and detailed. Some of these correspondences are still uncovered while some of them are further developed. This correspondence is reflected in the Maxwell-like form of the gravitational field tensor (the Weyl tensor), the super-energy-momentum tensor (the Bel-Robinson tensor) and the dynamical equations (the Bianchi identities). In this talk, we shall discuss some of the analogies between electromagnetism and gravitation.

SEMUA DIJEMPUT HADIR
Title: A Third-Order Runge-Kutta Methods for Directly Solving Special Third Order Delay and Ordinarily Differential Equations

Speaker: Mr. Mohammed Sahib Abed (SHB100019)

Date: 4 December 2013 (Wednesday)
Time: 4:00 – 5:00 pm
Venue: MM3, Institute of Mathematical Sciences

Abstract

A new s-stage third order Runge-Kutta methods for the direct integration of special third order ordinary differential equations (ODEs) are constructed. The methods are proven to be zero-stable. RKD methods are adapted for solving the special third order delay differential equations DDEs. The stability polynomial of the methods when applied to linear third order ODEs or DDEs are obtained. A two sets of test problems are tested upon, the first set consists of problems on ordinary differential equations and the second set consists of problems on delay differential equations. The problems are solved using the new RKD methods and numerical comparisons are made when the same problems are reduced to a first order system of ODEs and first order system of DDEs and solved using the existing Runge-Kutta methods of same order. The numerical results have clearly shown the advantage and the efficiency of the new methods in terms of accuracy and computational time.
The Weak Circular Flow Conjecture and Applications

Speaker: Prof. Carsten Thomassen  
Department of Mathematics  
Technical University of Denmark

Date: 13 December 2013 (Friday)  
Time: 3:00 pm – 4:00 pm  
Venue: MM3, Institute of Mathematical Sciences

Abstract

Tutte’s 3-flow conjecture says that every 4-edge-connected graph has an orientation such that, for each vertex $x$, the indegree of $x$ equals the outdegree of $x$ modulo 3. In 1988 Jaeger suggested a weaker conjecture obtained by replacing 4 by a larger (universal) number and called that the weak 3-flow conjecture. He also suggested a stronger conjecture, called the circular flow conjecture.

In this talk we indicate a proof of the weak circular flow conjecture (and hence also the weak 3-flow conjecture) and discuss its applications to graph decomposition, group flow, and factors modulo $k$. 
Title: Generalized Prolate Spheroidal Wave Signals

Speaker: Assoc. Prof. Kit Ian Kou
Department of Mathematics
Faculty of Science and Technology, University of Macau

Date: 23 December 2013 (Monday)
Time: 3:00 pm – 4:00 pm
Venue: MM3, Institute of Mathematical Sciences

Abstract

Prolate spheroidal wave functions possess many remarkable properties. They are orthogonal basis of both square integrable space of finite interval and the Paley-Wiener space of bandlimited functions on the real line. No other system of classical orthogonal functions is known to obey this unique property. This raises the question of whether they possess these properties in Quaternion analysis. The aim of the talk is to study this question. We also analyze the energy preservation problems.

SEMUA DIJEMPUT HADIR

Research Group: Statistical Modelling Research Group
Title: Transition from steady to chaos for Bénard convection saturated in porous medium

Speaker: Liew Kok Yee (SGP 100011)

Date: 20 December 2013 (Friday)

Time: 3:00 pm – 4:00 pm

Venue: MM3, Institute of Mathematical Sciences

Abstract

In this study, the transition from steady to chaos for the onset of Bénard convection in porous medium heated from below was analyzed based on the theory of dynamical system. A three ordinary differential equations model of chaotic system is obtained by the Galerkin truncated approximation. The range of Rayleigh number between 2 to 250 and Darcy number is 0.1 are used to analyze the system. Numerical results were shown in the form of bifurcation diagram and phase portrait. The transition from steady to chaos takes over from a limit cycle followed by a homoclinic explosion via a Hopf bifurcation.

SEMUA DIJEMPUT HADIR
Fraud activities have reached to a critical point causing millions of dollars of losses to telecommunication companies, and as a result, forcing them to employ applications or systems (such as data mining and Telekom Malaysia Berhad’s Next Generation Fraud Detection System) to detect the said activities. We introduce a new algorithm that (we believe) could detect fraud activities in telecommunication industry that uses Gaussian Mixed Model (or GMM), a probabilistic model normally used in fraud detection via speech recognition. Due to complexity of GMM, we use Expectation Maximization (or EM) by Dempster et al. (1977) to obtain the maximum likelihood estimate of the GMM parameters. Log-likelihood function, Akaike Information Criteria and Kernel method (see Silverman, 1986) are used to improve the process of finding the number of components in GMM. In addition, we have also successfully derived the likelihood ratio test in the determination of the number of components in GMM and the comparison of its results with those of AIC will also be highlighted in this thesis. The said algorithm also uses similarity coefficient to classify the real data based on log-likelihood function produced from earlier mentioned techniques. The algorithm is then extended to detect incoming fraud calls as suspected by the telecommunication company. The new algorithm (which incorporates the improved process of finding the number of components in GMM) is tested on simulation and real data where the results show it is capable of detecting fraud activities. The real data, consisting of amongst others call charging and duration, are collected from Telekom Malaysia Berhad’s exchanges and they are believed to be contaminated by fraud activities. As the original data are clearly not in the format that is generally used for speech recognition, they are re-arranged prior to testing and analysis activities. The said activities show that the fraud calls identified by the new algorithm agree with that suspected by the company.
Title: Representation Theory of C*-dynamical Systems

Speaker: Sriwulan Adji
Institut Sains Matematik (Universiti Malaya)

Date: 18 December 2013 (Wednesday)
Time: 3:00 pm – 4:00 pm
Venue: MM3, Institute of Mathematical Sciences

Abstract

C*-algebra is a subject in advanced functional analysis theory, it is an abstract characterization of the algebra of bounded operators on Hilbert spaces. The theory was first developed in quantum mechanics to model the algebras of physical observables. One of the most popular study in this subject involves a large class of C*-algebras, is called a Crossed Product C*-algebra. It is a C*-algebra built out of a C*-dynamical system, and this is the main topic that I am going to talk about in the seminar. I will begin with an introduction of C*-algebra theory, give some ideas to the construction of crossed product C*-algebra, and then discuss some basic examples.
Title: Second-order least-squares estimation for regression with autocorrelated errors

Speaker: Prof. Shelton Peiris
School of Mathematics and Statistics
University of Sydney (Australia)

Date: 2 January 2014 (Thursday)
Time: 10:00 – 11:00 am
Venue: MM3, Institute of Mathematical Sciences

Abstract

This talk considers the second-order least squares estimator (SLSE) for regression models with autocorrelated errors. We establish the asymptotic normality of the proposed SLSE estimator. A simulation study has been conducted to compare the performance of the SLSE with OLSE (Ordinary Least Square Estimator) and GLSE (Generalized Least Square Estimator). The simulation results confirm that the SLSE performs well in estimating the parameters of such models giving small bias. For less correlated data, it is shown that the standard error (s.e.) of SLSE lies in between those of the OLSE and GLS. For significantly correlated data, the structure becomes volatile and shown that the SLSE will be less robust than the OLSE. The s.e. of GLSE are the smallest, which is consistent with the theoretical result related to Gauss-Markov-Aitken theorem.
Title: Optimal Control For Fractional Dynamical Systems

Speaker: Prof. Dr. P. Balasubramaniam,
Department of Mathematics,
Gandhigram Rural Institute – Deemed University,
Gandhigram – 624302, Tamilnadu, India
E-mail address: balugru@gmail.com

Date: 8 Jan 2014 (Wednesday)
Time: 3.00 pm – 4.00 pm
Venue: MM3, Institute of Mathematical Sciences

Abstract

In this presentation, we are going to discuss some introduction and basics on fractional calculus, fractional dynamical systems. Then we discuss about the necessity of fractional dynamical systems and their applications in the field of control theory, optimal control theory and some of its real life applications. Finally we discuss about the formulation of Fractional Optimal Control Problems and some of its solution schemes.

Research Group: Centre for Mathematical and Statistical Modelling