BOOK OF ABSTRACTS

CHALLENGES IN STATISTICS AND OPERATIONS RESEARCH

March 8-10, 2011

Department of Statistics and Operations Research,
College of Science, Khaldiyah Campus
Kuwait University
P.O. Box 5969, Safat 13060
Kuwait

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CONFERENCE CHAIRMAN'S WELCOME:

I am greatly honored and pleased to welcome you all to the "*Challenges in Statistics and Operations Research",* the first international conference held by the Department of Statistics and Operations Research at Kuwait University to celebrate the 25th anniversary of its establishment. This event coincides with the 50th anniversary of the Independence of the State of Kuwait. Our aim is to bring together researchers /statisticians from all around the world to share their research findings in the fields of Probability, Statistics, Operations Research and their applications. The conference will enhance the interaction and collaboration among the participants both at national and international levels. Joint efforts and collaborations by the Kuwait University authorities and the members of the Department of Statistics and Operations Research have provided this opportunity to more than 100 colleagues from over 43 different countries, junior and senior scientists to participate in the conference. The state of Kuwait is proud of having its tradition of supporting scientific activities, regional and international.

This conference has benefited from the collaboration of many organizations that I would like to thank them all; in particular my sincere appreciation goes to the *Kuwait University, Kuwait Foundation for the Advancement of Science, Kuwait Finance House* for their major funding and sponsoring of the conference. Also, the following organizations have supported and sponsored the conference in part; **Companies:** *SAS, Minitab;* **Media Sponsers***: Alwasat, Alanbaa, Alseyasa, Alnahar, Alsabah.*

I thank you all. I wish the conference a great success, and hope you enjoy the CSOR 2011 and your stay in Kuwait.

Dr. Fahimah Al-Awadhi

KEYNOTE TALKS ABSTRACTS

Keynote Talk: Tuesday 10:30 – 11:15

Shifting Goals and Mounting Challenges for Statistical Science in the Wake of Multi-Disciplinary Research
Pranab K. Sen

University of North Carolina at Chapel Hill, USA.

Abstract. The genesis of statistical science signals a clear-cut picture of diverse factors that led to the development of this broad field of research and practice. Although mathematical foundations were paramount in the development of theoretical perspectives, the basic need for reconciliation with various other disciplines in all walks of life and science has been a prime factor in the augmentation of theory to suit the imparting of better understanding and interpretation of their underlying stochastic as well as deterministic aspects. The goals have always been shifting from the very inception and will be even more in future. Nevertheless, the current emphasis on information technology and data mining in all walks of life and science, particularly in financial economics, social and economic science, clinical research, environmental health sciences, pharmaco - and toxico-genetics and bioinformatics at large, has opened a pandora's box for statistical and computer sciences. Coping with the emergence of massive data sets in astounding details and incredible pace has been genuinely challenging from statistical validation and interpretation perspectives. Some of these mounting challenges are assessed with possible statistical resolutions.

Keynote Talk: Tuesday 11:15 – 12:00

Service Industries and the Emergence of "Service Science"
Richard C. Larson

Massachusetts Institute of Technology, USA.

Abstract. "Number please." These words were one once heard when picking up the telephone to make a call. Yes, a human telephone operator was involved in making each connection. This snippet from post-World-War-II history is illustrative of what once was and no longer is in service industries. Most services which were once labor intensive have replaced human servers with technology and/or with the customer herself performing the service, i.e., "self-service." Examples include ATM's (Automatic Teller Machines), elevators, supermarkets, self-service gasoline stations, purchase of goods and services via the Internet, check-in at airports, and even various postal services. Almost all of this has occurred in the last 60 years, post World War II, a time during which the service sector has grown to 75% or more of the economies of most industrialized nations. In this presentation, we review these trends by example and then illustrate some of the decision and modeling technologies that have played key roles in the transformation. This focus on services has created a new field called "Service Science." From an Operations Research perspective, Service Science has methodological roots going back centuries: Euler's birth of graph theory, so important in transportation and logistics; A.K. Erlang's birth of queueing theory, vital in almost all service industries; and optimization – also important almost everywhere. But the coalescing of the emerging field now known as Service Science has created new opportunities, building upon our OR traditions and expanding to include rich aspects of management and social science. We give examples in communication, health care, transportation/logistics, energy management and education.

Keynote Talk: Tuesday 14:30 – 15:15

Real Options
A. Bensoussan

University of Texas at Dallas, USA.

Abstract. Real Options theory is an approach to mitigate risks of investment projects, which is based on two ideas. The first one is Hedging, borrowed from financial options, when market considerations can be introduced. The project risk must be correlated to the market risk, in which case tradable assets can be used to hedge. The second idea is flexibility. There is Flexibility in the process of decision making. In particular, one may scale down or up the project, one may stop it, one may change orientation. This flexibility allows reacting properly when Information is obtained on the uncertainties of the evolution. We review in this presentation some of the major possibilities of flexibility, to defer, to abandon, mothballing. We also consider some extensions on the investment cost, for instance the situation of tax incentives. We show that the technique of Variational Inequalities is the right mathematical tool to model these situations. The models are developed in continuous time, where the elegant rules of Ito's calculus apply. The concepts are discussed independently of these techniques. We also consider the possibility of competition and the situation of incomplete markets. (Co-author: A. Smith)

Keynote Talk: Tuesday 15:15 – 16:00

Recent Developments in Objective Bayesian Statistics
José M. Bernardo

Universitat de València, Spain.

Abstract. Important statistical inference summaries include point estimation, region estimation, and precise hypotheses testing. Form a Bayesian viewpoint, those summaries may appropriately be described as the solution to specific decision problems which depend on the particular loss function chosen. The use of a continuous loss function leads to an integrated set of solutions where the same prior distribution may be used throughout. Objective Bayesian methods use a non-subjective prior and produce results which only depend on the assumed model and the data obtained. The combined use of the intrinsic discrepancy, an invariant information-based loss function, and appropriately defined reference priors, provides an integrated objective Bayesian solution to both estimation and hypothesis testing problems.

Keynote Talk: Wednesday 8:30 – 9:15

Forecasting Phenological Events
James V Zidek

University of British Columbia, Canada.

Abstract. Although it is certain that world climate is changing, the degree, nature and impact of that change are not. Thus attention has increasingly turned to dynamically managing the risks of that change as it progresses in the future. Declining food production is one such risk and the subject of this talk, which falls under the heading of agroclimate risk management. More specifically it concerns the prediction of phenological change both within a year and over time. For example, in any one season an apple tree bears fruit after a sequence of other phenological events including bud - burst and blooming. The successive times of these events will vary randomly from year - to - year due to weather, while exhibiting trends over time due to climate. Modeling such sequences lies in the domain

of time – to – event analysis, a branch of survival analysis. However, it has special features that put it outside the ambit of existing theory. First the events are progressive, i.e. irreversible, if they occur at all. Second the time to occurrence of any one event, becomes a predictor to the time to the next. Third the covariates are time – varying and the occurrence of any one event depends not just on the covariate's value at that time, but on the whole sequence of its values since the beginning of the year of interest. Finally, the goal is prediction, not hypothesis testing, the usual goal of survival analysis. Thus the work to be described in this talk will consist first of a description of an extension to time - to – event theory to cover this application. Then I will describe its application to prediction of the bloom dates of perennial crops in the Okanagan region of British Columbia. That application entails the construction of a predictive distribution for the relevant within year covariates (climate variables). I expect to be able to report on the results of downscaling climate models to enable the determination of future trends based on ongoing work. (Co-author: S. Cai)

Keynote Talk: Wednesday 9:15 – 10:00

Mathematical Models for Territory Design and Extensions
Stefan Nickel

Karlsruhe Institute of Technology and Fraunhofer Institute for Industrial Mathematics
Germany.

Abstract. Territory design may be viewed as the problem of grouping small geographic areas called basic areas (e.g. counties, zip code areas, company trading areas) into larger geographic clusters called territories in such a way that the latter meet the relevant planning criteria. Especially, the availability of GIS on computers and the growing interest in Geo-Marketing lead to an increasing importance of this area. Territory design problems treated by operations researchers are motivated by quite different applications ranging from political districting to sales and service territory design. Hereby, one can observe that only few papers consider districting problems independent from a practical background. However, when taking a closer look at the proposed models for the different applications, a lot of similarities can be noticed. Indeed the developed models are many times quite similar and can often be, more or less directly, carried over to other applications. Therefore, our aim is to provide a general, application–independent model for territory design problems and present efficient solution techniques. In this talk we will first review several typical applications for territory design problems and try to identify essential elements, common to all applications. Afterwards we will compile a model, which covers several of these aspects. Then a short overview of models and solution techniques found in the literature for solving districting problems will be given. We will then focus on two methods for solving the problem: the commonly used location–allocation approach combined with optimal split resolution techniques and a new method which is based on ideas from the field of computational geometry. Some computational results of the new approach and possible extensions are presented. We also show how the presented techniques are successfully integrated into a commercial GIS and give some general idea on how GIS and optimization methods can interact. In the last part of the talk we will address a recent variant of the territory design problem arising in the context of reverse logistics. The problem is motivated by the new recycling directive WEEE of the European Community. The core of this law is that each company which sells electrical or electronic equipment in a European country has the obligation to recollect and recycle an amount of returned items which is proportional to its market share. To assign collection stations to companies in Germany for one product type, a territory design approach is planned. However, in contrast to classical territory design, the territories should be geographically as dispersed as possible to avoid that a company, resp. its logistics provider responsible for the recollection, gains a monopoly in some region. First, we identify an appropriate measure for the dispersion of a territory. Afterwards, we present a first mathematical programming model for this new problem as well as some improvements. Extensive computational results illustrate the suitability of the model.

Keynote Talk: Thursday 8:30 – 9:15

Multi-Class Data Exploration Using Space Transformed Visualization Plots
Ali S. Hadi

The American University in Cairo, Egypt.

Abstract. Visualization of large data sets is computationally expensive. For this reason, enveloping methods have been used to visualize such data sets. Using enveloping methods, we visualize summary statistics of the data in the space transformed visualization (STV) plots, such as the traditional parallel coordinate plot (TPCP), instead of the actual data records. Existing enveloping methods, however, are limited only to the TPCP and they can also be misleading. This is because the parallel coordinates are parameter transformations and the summary statistics computed for the original data records are not preserved throughout the transformation to the parallel coordinates space. We propose enveloping methods that avoid this drawback and that can be applied not only to the TPCP but also to a family of STV plots such as the smooth parallel coordinate plot (SPCP) and the Andrews plot. We apply the proposed methods to the min-max, the quartiles, and the concentration interval envelopes (CINES). These enveloping methods allow us to visually describe the geometry of given classes without the need of visualizing each single data record. These methods are effective for visualizing large data sets, as illustrated for real data sets, because they mitigate the cluttering effect in visualizing large-sized classes in the STV plots. Supplemental materials, including R-code, are available online to enable readers to reproduce the graphs in this paper and/or apply the proposed methods to their own data. (Co-authors: R. E. Moustafa and J. Symanzik)

Keynote Talk: Thursday 9:15 – 10:00

Business Analytics for Decision Making: Making It Work
Gary Cokins

Performance Management Solutions, SAS, USA.

Abstract. A recent survey by the consulting firm Accenture reported that most companies are far from where they want and need to be when it comes to implementing analytics and are still relying on gut feeling, rather than hard data, when making decisions. What is needed today is the seamless integration of managerial methodologies such as balanced scorecards, strategy maps, risk management, budgets, activity-based costing (ABC), forecasts, customer relationship and value management, and resource capacity planning. Each one should be embedded with business analytics, especially predictive analytics. Volatility is the new normal. Analytics with statistics, including regression and correlation analysis, provide organizations with insights to make better decisions and take actions. The performance management methodologies are collectively intended to align manager and employee behavior and limited resources to focus on the organization's strategic priorities and objectives. Performance management focuses on execution. Its purpose is not just better financial reporting and monitoring dashboard dials but on moving the dials – improving performance. Information technology specialists complicate progress with a common misconception by equating business intelligence (BI) technologies such as query and reporting techniques with advanced analytics like data mining and forecasting. But in practice experienced analysts don't use BI, instead they first speculate that two things are related or that some underlying behavior is driving a pattern to be seen in various data. They apply business analytics more as confirmatory than somewhat random exploratory. In this presentation, the following topics will be covered.

What forces have caused interest in business analytics and statistics? What is the difference between business analytics and business intelligence. How applying business analytics increases the power of performance management methodologies. Why business analytics, with emphasis on predictive analytics and pro-active decision making, is becoming a competitive advantage differentiator and an enabler for trade-off analysis. How activity-based cost management (ABC/M) provides not only accurately traced calculated costs (relative to arbitrary broad-averaged cost allocations), but more importantly provides cost transparency back to the work processes and consumed resources, and to what drivers cause work activities. How all levels of management can quickly see and assess how they are doing on what is important – typically with only a maximum of three key performance indicators (KPIs). How to integrate performance measurement scorecards and ABC/M data with: Strategy formulation; Process-based thinking and operational productivity improvement; Channel/ customer profitability and value analysis and CRM Supply chain management; and Quality and lean management (Six Sigma, cost of quality).

CONTRIBUTED TALKS ABSTRACTS

STAT-T1A Tuesday, 12:15 – 13:30

On Optimal Spline Smoothing of the Hodrick-Prescott Filter

Boualem Djehiche[1], Mårten Marcus[1] and Nadji Rahmania[2]

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Abstract. We suggest an explicit formula of the optimal smoothing B-spline trend which is consistent with the Hodrick-Prescott filter in the sense that the smoothing spline function agrees with the Hodrick-Prescott trend at the knots. We also compare its numerical performance with other trend estimates such as the standard Hodrick-Prescott and the generalized cross-validation trend estimates.

Keywords: Adaptive estimation, Gaussian process, B-spline function, optimal approximating splines, Hodrick-Prescott filter, noise-to-signal ratio, smoothing, trend extraction, generalized cross-validation.

Prediction via the conditional quantile for right censored and dependant data

Ourida Sadki[1] and Elias Ould-Saïd[2]

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[2]L.M.P.A. J. Liouville,Univ. du Littoral Côte d'Opale BP 699, 62228 Calais, France.

Abstract. We consider a smooth estimator of the conditional quantile function in the censorship model in the α-mixing case. Consider a sequence of strictly stationary rv's $T_1, T_2, ...$ with common unknown absolutely continuous df F. In many situations, we observe only censored lifetimes of items under study. That is, assuming that $C_1, C_2, ..., C_n$ are n censoring rv's with common unknown continuous df G, we observe only the sequence $\{(Y_i, \delta_i, X_i), i = 1, 2, ..., n\}$. where $Y_i = T_i \wedge C_i$ and $\delta_i = I_{(T_i \le C_i)}$, and X is a covariate. We suppose that $\{T_i, i \ge 1,\}$ and $\{C_i, i \ge 1,\}$ are two independent sequences of stationary α-mixing rv's.

We show that, under some regularity conditions, our estimator converges uniformly almost surely and suitably normalized is asymptotically normal. We give an application to a prediction. Some simulations have been drawn to lend further support to our theoretical results for the finite samples.

Keywords: Conditional quantile function, Censored data, Kernel estimator, Strong-mixing.

Two-Phase Sample Size Estimation with Pre-assigned Variance

Mohammad Salehi M

Department of Mathematics, Statistics and Physics, Qatar University, P. O. Box 2713, Doha, Qatar,

Abstract: We develop a two phase sampling procedure to determine the sample size necessary to estimate the population mean of a normally distributed random variable and show that the resulting estimator has pre-assigned variance and an unbiased under a regular condition. We present a necessary and sufficient condition under which the final sample mean is an unbiased estimator for the population mean.

Key words: population mean, sample size determination, two phase sampling.

STAT-T1B Tuesday, 12:15 – 13:30

A step-wise method for labeling continuous data with a focus on striking a balance between predictive accuracy and model reliability

Kassim S. M. Mwitondi[1] and Raed A. T. Said[2]

[1] Sheffield Hallam University; Department of Computing, U.K.
[2] Al Ain University of Science and Technology.

Abstract. The paper proposes a step-wise method for striking a balance between predictive accuracy and reliability of unsupervised and supervised models. Its key strategy involves using methods initially developed for detecting outliers in data to identify naturally arising patterns in continuous data. The detected natural groupings are simultaneously labelled based on internally-devised data-dependent parametric rules before carrying out predictive modelling using decision trees and neural networks models. Using the two models, the method is applied in identifying patterns in simulated and real data obtained from seismic signal readings, x-ray fluorescence clay analyses, an African cancer registry and stock market performances. Repeated analyses across the four applications show that the method not only achieves higher predictive accuracy than the conventional approaches, but also resists data over-fitting. The paper makes key recommendations relating to the future of knowledge extraction from data and highlights future challenges and opportunities. In particular, it focuses on addressing model complexity issues by appropriately taming data sources, models and related parameters in a monitored triangular balance. The concept of triangular balance forms the basis for data recycling and generation on the one hand and model development and enhancement on the other - both instrumental in knowledge extraction from data.

Keywords; Accuracy, data mining, data recycling, decision trees, neural networks, over-fitting, seismic signals, supervised modelling, XRF, unsupervised modelling

A family of tests for exponentiality against IFR alternatives

M. Z. Anis

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Abstract. The assumption of exponentiality is widely used in the theory of reliability and life testing. This essentially implies that a used item is stochastically as good as a new one. The unit in question does not age with time. Hence, there is no reason to replace a unit which is working. However, this is not always a realistic assumption; and age does have an effect on the residual life time. Positive (negative) aging means that age has an adverse (beneficial) effect, in some probabilistic sense, on the residual life. Hence, it is of interest to check possible departure from exponentiality in the data.

A practical notion of aging is that of an *increasing failure rate* (IFR). The IFR class exhibits the strongest aging behaviour. In this paper we develop a family of test statistics for testing exponentiality against IFR alternatives. The major advantage in having a family of tests statistics for a testing problem is that we may be able to identify members of the family that have maximum power of efficiency. We define a weighted measure of deviation from the null hypothesis of exponentiality towards the IFR alternative; and consider an average value of this deviation. The null hypothesis is rejected for large values of this deviation measure. The deviation measure is a function of the weights used and hence we have a family of tests.

It is shown that the class of test statistics is an *L*-statistic. We derive its exact distribution and show that it is asymptotically normal. We also prove that the test is consistent. We compare the efficiency for different members in the family of tests statistics when testing against some different alternatives. Examples are used to indicate how the testing procedure can be carried out.

Keywords: Asymptotic normality; Hazard rate; Normalized spacings; Order statistics.

Moments of the Reliability R = P(Y<X) as a Random Variable

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Abstract. The estimation of $R = P(Y<X)$ when X and Y are independent and identically distributed random variables has been extensively studied in the literature. Algebraic forms of R, for different distributions, also have been studied in the literature.   Among those distributions which were considered are the normal, exponential, gamma, Weibull, and Pareto. Recently, extreme value family was investigated by Nadarajah (2003). Haghighi and Shayib (2009) have considered the logistic and extreme value distributions. In all cases, X and Y are assumed to be independent random variables. If $H_Y(y)$ and $f_X(x)$ are the cumulative distribution function (*cdf*) and the probability density function (pdf) of Y and X, respectively, then it is well known that

$$R = P(Y < X) = \int_{-\infty}^{\infty} H_Y(z) f_X(z) dz. \tag{1}$$

The objective of this article is to derive the probability density function (pdf) of R, under the assumption that the parameter of the distribution under investigation is itself a random variable with some specified pdf. Once the pdf of R is derived, its moments and other properties can be investigated. We will consider several distributions including the exponential, Chi-Square, gamma, Weibull, and Burr Type X. It has been found that the Moment Generating Function Techniques, for finding the moments, do not work, in the sense that they will not yield a closed form.

OR-T1 Tuesday, 12:15 – 13:30

On a finite horizon EOQ model with cycle dependent trade credit policies and time dependent parameters

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Abstract. In most inventory models it is assumed that the parameters of the model do not vary with time, and that the payment of orders from the retailer to the supplier is made immediately upon the receipt of these orders. Some suppliers, however, allow a certain fixed period to settle payment accounts. During this fixed period no interest is charged by the supplier, but beyond that period an interest, with the conditions agreed upon, is charged on the retailer. However, an interest can be earned by the retailer from the revenue that he receives during the given credit period. In this paper we develop and solve a general finite horizon trade credit economic ordering policy for an inventory model with deteriorating items where each of the demand, deterioration rates as well as all cost parameters are known and are arbitrary functions of time. Both inflation and time value of money are incorporated in all cost components. The time horizon is divided into different cycles each of which has its own demand rate and its own trade credit period offered from the supplier to his retailer so that the retailer should pay his supplier before or after the end of the permissible trade credit of that cycle. Shortages are not allowed in any cycle. The objective of the retailer is to minimize his net total relevant costs. A closed form of this net total cost is derived and the resulting model is solved. Then rigorous mathematical methods are used to show that, under some seemingly possible conditions, there exists a unique vector of the relevant decision variables that solve the underlying inventory system.

Keywords: General EOQ; Variable trade credit polices; Optimality; Deterioration; Inventory control; Time dependent parameters. Inflation, Time value of money.

Optimized Synthetic Quality Control Charts for In-control and Out-of-control Regions

Francisco Aparisi and Andrés Carrión

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Abstract. Although the large majority of the research in Statistical Process Control (SPC) is based on finding new control charts to detect effectively small process shifts, in some real applications it is necessary to design a control chart that does not detect small shifts, but keeps a good performance to detect moderate and large shifts. Some examples are processes that are very capable, processes that are very difficult to adjust or processes where the cost of correcting a small shift is very high. In all theses cases is assumed that the small process shifts to not be detected do not produce a significant loss in quality. Hence, we have two regions to be considered: the in-control region, where small shifts are not to be detected; the out-of-control region, where the shifts are to be detected as soon as possible. This design problem can be posed as a multi-objective optimization problem. The first objective is maximizing the ARL for the in-control region. The second objective is to minimize the ARL for the out-of-control region. We have found that the synthetic-Xbar control chart can solve very well this optimization problem. In addition, we have developed the multivariate version of this chart, the synthetic-T^2 control chart, which is very adequate for the multivariate case. In order to solve this multi-objective optimization problem, we have developed friendly Windows software that obtains the Pareto Front, showing the parameters of the synthetic charts (Xbar and T^2) that represent the non dominated solutions. Employing this software, the practitioner in industry can easy find the best chart for his/her process.

Keywords: Quality Control, SPC, Pareto Front, Multi-objective Optimization.

Warranty servicing for multi-state degrading items with non-zero repair time under renewing warranty

Hashem Vahdani, Hashem Mahlooji and Abdol Hamid Esharghnia Jahromi

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Abstract. This paper considers a repair-replacement strategy for a special class of discretely degrading and repairable products under renewing free replacement warranty. Each product may experience N different working states with different exponential hazard functions, before the warranty contract expires. Once the item enters working state *j* (*j=1, 2, ..., N*), it can either fail or move to any of the subsequent working states with different probabilities, given that a transition occurred. In the former case, the best rectification action, replacement or minimal repair, regarding the failure status: the product degradation level at the time of the failure and the remaining warranty time, should be done to put the item into operation. It is assumed that replacement of the faulty item occurs instantly and the product warranty is renewed, but non-zero repair time has been included in the model with an increasing order with respect to the failure states. We derive the optimal replacement-repair policy to minimize the expected warranty servicing cost per item sold. A simulation based optimization method has been developed to analyze the expected warranty cost. A Numerical example is given to clearly demonstrate the application of this model.

Keywords: Maintenance, Multi-state, Renewing Warranty, Simulation.

STAT-T2A Tuesday, 16:15 – 17:30

Local Depth for Functional Data
Claudio Agostinelli and Mario Romanazzi

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Abstract. Depth functions provide center-outward ranks which are monotonically decreasing along any given ray from the deepest point. As a consequence, they are unable to reveal multiple centers and data clustering occurring in multimodal and mixture distributions. To overcome this problem, we introduce the class of local depth functions [Agostinelli and Romanazzi, 2011]. Essentially, local depth

evaluates centrality conditional on a neighbourhood of each point of the reference space. These generalized depth functions are able to record local fluctuations of the density function and they can be used in mode detection, identification of components in mixture models and in cluster analysis.

Here we concentrate on the analysis of functional data, e.g., continuous trajectories of a process, time series, irregularly spaced time series. We suggest a local version for the band depth [López-Pintado and Romo, 2009]. We also introduce a new criterion for measuring depth functional data which considers the epigraph of a trajectory. Several real data set examples are illustrated with a comparison of different definitions.

Keywords: Band Depth, Clustering, Data Depth, Functional Data, Irregularly spaced Time series, Local Depth.

Bayesian tomographic restoration of Ionospheric electron density using Markov Chain Monte Carlo techniques

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Abstract. The ionized region of the Earth's atmosphere is known as the ionosphere. The ionosphere is not static because electron concentrations vary considerably with time, season and intensity of solar radiation. Due to the large concentration of free electrons the ionosphere affects all radio waves including those transmitted by the Navy Navigation Satellite System (NNSS) and the Global Positioning System (GPS), causing errors. Thus one of the most important physical parameters in the ionosphere is the electron density, and accurate knowledge of its spatial distribution is essential. In Ionospheric tomography the data are integrals of total electron density along many intersecting paths, and are usually collected from satellite-to-ground based receivers. These data are inverted to reconstruct an image of electron density in the ionospheric plane under study. We propose a Bayesian approach to the inversion problem using spatial priors. To obtain inferences the Bayesian approach is accompanied with a special Markov Chain Monte Carlo algorithm that we developed. The algorithm is based on a principle components analysis of initial output.

Keywords: Bayesian modeling, Ionospheric Tomography, Markov Chain Monte Carlo, Principle Components, Inversion

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A New Approach to Modeling Count Data in Reproductive and Developmental Toxicity Experiments

Mehdi Razzaghi

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Abstract. In reproductive and developmental toxicity experiments, pregnant female laboratory animals are exposed to a dose of a chemical during a critical time of the gestation period. The animals are sacrificed prior to term and the uterine contents are examined for a variety of abnormalities such as death, malformation and resorption. Statistical techniques for evaluation of outcomes from such experiments generally focus on continuous or proportion data. However, there are many instances where the endpoints of interest are measured as counts. Due to the existence of the intra-litter correlation, a complication that arises in the analysis of count data is the fact that a simple Poisson distribution does not adequately represent the observed variation. Traditionally, a model based on a gamma-Poisson distribution in which one assumes that the mean of the Poisson has a gamma distribution is used. This approach leads to a variable with a negative binomial distribution. Here, we propose an alternative approach and use a Poisson-Lindley distribution for modeling count data. In such distributions, the Poisson mean is modeled by the Lindley distribution. The Poisson-Lindley distribution is known to provide a good approximation to the negative binomial

and the Hermite distributions. The properties of the new modeling approach are explored and a numerical example is used to provide further illustration.

Keywords: count data, developmental toxicity, intra-litter correlation, Poisson-Lindley.

STAT T2B Tuesday, 16:15 – 17:30

Computation of Risk Function in Conditional Bayesian Problem of Testing Many Hypotheses
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[2]Abdus Salam School of Mathematical Sciences of GC University, Lahore, Pakistan.

Abstract. The computation of the risk function in Bayesian methods of hypotheses testing is very important, because it is the objective criterion of the quality of the Bayesian decision rule. Therefore, the solution of this problem when hypotheses are formulated concerning all parameters of the multivariate normal distribution is considered in this paper. For this purpose the expansion of the distribution function of random variable by series is used. Formula for calculation of the initial moment of the r th order of the weighted sum of the exponents of negative quadratic forms of the normally distributed random vector with correlated components is obtained. The fact of correctness of the offered expansion and opportunity of computation of the risk function with necessary accuracy is shown.

Keywords: hypothesis test, risk function, probability integral, moments, series.

A conditional Bayesian approach for testing independence in two-waycontingency tables
M. Ganjali and Z. Saberi

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Abstract. Bayesian methods for exact small-sample analysis with categorical data in I by J contingency tables are considered. Point null hypothesis versus two-sided hypothesis is tested concerning log odds ratios in these tables with fixed row margins. The conditional distribution of sufficient statistics for interesting parameters conditional on sufficient statistics of other nuisance parameters in the model is obtained and used to eliminate the effect of nuisance parameters. This distribution is Fisher's multivariate noncentral hypergeometric distribution. For Bayesian approaches, hierarchical Bayes, empirical Bayes, and noninformative Bayes are considered and compared by simulation studies. Bayes factor and Bayesian P-value are used as measures for evidence. A conjugate prior at the first stage and a noninformative prior at the second stage are used for the hyperparameters in the hierarchical approach. These Bayesian approaches are also compared with some classical methods. The overall results show a better performance of empirical Bayes approach in comparison with those of classical, hierarchical and noninformative approaches.

Keywords: Bayes Factor; Bayesian P-value; Hierarchical Bayes; Important Sampling; Noncentral Hypergeometric Distribution; Small-sample.

Performance Evaluation of Imputation Based on Bayesian Networks

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Abstract. The issue of missing data may arise for researchers who deal with data gathering problems. Different methods of missing data imputation have been proposed to deal with such problems. The Bayesian Network is one of the proposed methods that has been recently used in missing data imputation. In this research, to consider the effect of different kinds of missingness mechanism (ignorable and nonignorable) on the performance of imputation methods, three methods of imputation: random overall hot-deck imputation, within-class random hot-deck imputation and imputation using Bayesian Networks are compared using two indices: (1) a distance function and (2) Divergence Kullback-Leibler index. In addition, by applying Value of Information Analysis (VIA), the performance of Bayesian Networks when the missingness mechanism is nonignorable, is examined and compared with that of Bayesian Networks constructed from data perturbed by ignorable mechanisms. The comparison is made using Mean Value of Information (MVI) index. Results indicate the high-quality of Bayesian Networks relative to other imputation methods.

Keywords: Bayesian Networks, Missing data, Imputation, Hot-deck imputation, Kullback-Leibler information, Value of information analysis.

OR-T2 Tuesday, 16:15 – 17:30

The knapsack Sharing problem: an adaptive search algorithm

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Abstract. In this paper, we study the knapsack sharing problem, a variant of the well-known NP-Hard single knapsack problem. We investigate the use of an adaptive algorithm for solving heuristically the problem. The used method combines two complementary phases: a size reduction phase and a dynamic 2-opt procedure one. First, the reduction phase applies a polynomial reduction strategy; that is used for reducing the size problem. Second, the adaptive search procedure is applied in order to attain a feasible solution. Finally, the performances of two versions of the proposed algorithm are evaluated on a set of randomly generated instances.

A Particle Swarm Optimization Algorithm for the Economic Lot Scheduling Problem

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Abstract. The Economic Lot Size Scheduling Problem(ELSP) is an NP hard inventory problem where the aim is to schedule the production of several different items in the same facility on repetitive basis. Due to the difficulty of checking the feasibility of a schedule, some researchers developed approaches in which additional constraints that guarantee feasibility are added to the problem. An optimal solution to the modified problem is then found. The Basic Period (BP) approach is one which guarantees feasibility by making the cycle of each product an integer multiple of a basic cycle time known as the fundamental cycle. The BP approach results in a problem that has one continuous decision variable (the fundamental cycle) and a number of integer decision variables (the integer multipliers) equal to the number of products. This paper presents a particle swarm optimization (PSO) algorithm to solve the economic lot scheduling problem (ELSP) with the Basic Period (BP) approach. The PSO algorithm is tested on Bomberger's classical problem. For different utilization levels on the benchmark instance, the performance of the PSO algorithm is compared to a genetic algorithm (GA). The computational results show that the proposed PSO algorithm is very competitive to or even slightly better than the GA present in the literature.

Keywords: Economic lot scheduling problem, genetic algorithm, particle swarm optimization algorithm, Heuristic optimization.

A Triggered Particle Swarm Optimization

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Abstract. This paper presents a modification of the particle swarm optimization (PSO) algorithm intended to tackle two difficulties observed in many applications of PSO, which are the premature convergence of the solution, and the degree of confidence that the decision maker should be satisfied by the obtained solution. This approach treated the PSO by triggering the particle swarm optimizer in a dynamic environment, this is accomplished by making each particle to reset its record of its best position, to avoid making direction and velocity decisions on the basis of outdated information, this is done by triggered resetting, based on the iteration count. Also the solution was tackled by introducing within certain uncertainty at a specific confidence level. The proposed algorithm, named a triggered particle swarm optimization (T -PSO), is shown that it performs significantly better than the original PSO and the new particle swarm optimization (NPSO)

Keywords: Particle Swarm Optimization, Dynamic Environments, Uncertainty

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STAT-W1A Wednesday 10:30 – 12:00

Locally D-Optimal Design for Logit Models
Habib Jafari[1]

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Abstract. Discrete choice experiments play an important role in psychology and market research when measuring the consumer's preferences. Usually, the choice behavior is modeled by a multinomial response, where the probabilities of the preferences are given by a logistic model. The resulting "independence of irrelevant alternatives" property of this model, may lead to counter-intuitive results. To avoid these pitfalls, "nested multinomial logit models" have been introduced that allow correlations between the utilities of similar alternatives. In this talk, we consider some choice sets each with the same number of alternatives to obtain locally D-optimal design. In this situation, according to the number of alternatives in each nest there are some classes to define design. Afterward, a design which is produced by combination of designs (related to classes) will be defined and we obtain locally D-optimal deign for it.

Keywords: Logit models; Multinomial Logit Model (MNL); Nested MNL Model; Locally D-optimal Criterion; Locally D-optimal Design.

Likelihood inference on the relative risk in split-cluster designs
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[2] Department of Biostatistics and Epidemiology, King Faisal Specialist Hospital and Research Center, Riyadh, Saudi Arabia.

Abstract. Split-cluster experiments are being used by investigators in health sciences when naturally occurring aggregate of individuals with nested subgroups may be assigned to different treatments. The major attractiveness of this design is that it removes a large portion of the inter-subject variation from the estimates of the treatment effect; hence has the potential to require lesser number of subjects than a parallel arm design with the same power. When the response variable of interest is binary, statistical methods developed to evaluate the effect of interventions depended on non-parametric methods. Though these methods are simple to apply, they are known to be less efficient. Taking the relative risk (RR) as an effect measure, we construct a bivariate correlated model under which a score test is applied to test Ho: RR=1.0. Moreover, we construct Wald and Fieller-based confidence intervals. A measure of model goodness of fit will be discussed as well.

Keywords: Cluster randomization; Intra-cluster correlation; Score testing; Canonical representation

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Qazi Motahar Hussain (1897-1981): Life and Statistical Contributions of a Pioneer Muslim Statistician
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Abstract. Qazi Motahar Hussain (QMH) was among the pioneers of statistics in the Indian subcontinent and very closely associated with P. C. Mahalanobis, the founder of the Indian statistical Institute (ISI). In this article some of the achievements of QMH in terms of research as well as spread of statistical education in the then East Bengal (later East Pakistan and now Bangladesh) and West Pakistan (now Pakistan) are highlighted. In particular, emphasis is laid on the significance of QMH's research contributions and commentaries are provided on the results of his major publications.

Keywords: Design of Experiments, Qazi Motahar Hussain, Statistical Education.

On the Renewal Risk Model with Constant Interest Force
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[2]Department of Mathematics, NITC, Calicut-673601, India.

Abstract. This paper investigates the non-ruin probability in a renewal risk model with constant interest force for an insurance portfolio. We first show that the survival probability function of the insurance risk model $\phi_\delta(u)$ satisfies an integro-differential equation and its Laplace-Stieltjes transforms have been derived. We also provide a recursive algorithm for the upper and lower bounds for the ruin probability under interest force. Finally, we derive an exponential integral equation for the survival probability. Some special cases are also discussed with numerical illustration.

Keywords: Generalized Exponential distribution, Probability of ruin, Constant interest force, Laplace-Stieltjes transform, Recursive calculation.

STAT-W1B Wednesday 10:30 – 12:00

A nonparametric conditional mode estimate under RLT model and strong mixing condition
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Abstract. Let $(Y_N)_{N \geq 1}$ denote a sequence of random variables of interest and $(\mathbf{X}_N)_{N \geq 1}$ be a sequence of R^d - valued covariates. Let $\Theta(x)$ denote the conditional mode of Y given $\mathbf{X}= x$. In the present paper, we study a kernel conditional mode estimator (say) $\hat{\Theta}_n(x)$, of the conditional mode of a randomly left truncated (RLT) variable Y. Given a sample $(\mathbf{X}_i, Y_i)$, $1 \leq i \leq n(n \leq N)$, of truncated replicates of $(\mathbf{X}, Y)$, which fulfill the well-known α −mixing hypothesis (strong mixing condition), the goal is to establish the strong uniform consistency of the proposed estimator $\hat{\Theta}_n(x)$ as well as the convergence rate.

Keywords: Kernel conditional mode estimator, Lynden-Bell estimator, random left-truncation (RLT) model, strong mixing condition, uniform almost sure convergence.

Comparison between different Stratified sampling methods to estimate the population mean

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[3] Al al-Bayt University, Faculty of Sciences, Department of Mathematics, P.O. Box 130040, Mafraq 25113, Jordan.

Abstract. Many methods related to stratified ranked set sampling are suggested for estimating the population mean. Some of these methods are stratified quartile ranked set sample (SQRSS), stratified percentile ranked set sample (SPRSS) and stratified median ranked set sample (SMRSS). These estimators are compared to stratified simple random sample (SSRS) and stratified ranked set sample (SRSS). It is found that all estimators are unbiased estimators of the population mean and are more efficient than their counterparts using SSRS and SRSS. A simulation study is considered to compare the efficiency of the above estimators.

Keywords: Stratified simple random sample, stratified ranked set sampling; stratified quartile ranked set sampling; stratified median ranked set sampling; stratified percentile ranked set sample.

On the Bayes Estimators of the Parameters of Generalized Power Series Distributions
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Abstract. In this paper we derive the Bayes estimators of functions of parameters of the Size-Biased Generalized Power Series Distribution (SBGPSD) under squared error loss function (SELF) and weighted square error loss function (WSELF). The results obtained for Size-Biased GPSD are then applied to its particular cases like Size-Biased Negative Binomial (SBNB), Size-Biased Logarithmic Series (SBLS), and Size-Biased Poisson (SBP) Distributions. These estimators are better than the classical minimum variance unbiased estimators (MVUE) in the sense that they increase the range of the estimation and also have simpler form. Finally, some numerical examples have been presented to illustrate the results.

Keywords and Phrases: Posterior distributions, SBGPSD, Squared Error Loss Function (SELF), Weighted Squared Error Loss Function (WSELF), Bayes Estimators.

M-Centering in Robust Estimation of Fixed Panel Data

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[2]Institute of Mathematical Research (INSPEM), Universiti Putra Malaysia, Serdang, Malaysia.

Abstract. There are scarce literatures regarding the robust estimation for panel data even though outliers are expected to exist prominently in this type of data setting. The outlying values are often found to be concentrated in a few time series. They can also occur either vertically, horizontally or leverage. Any form of deviations caused by outliers can tremendously affect the parameter estimation of the classical fixed effect model. The parameter estimates become unreliable, bias and dysfunctional. Therefore, this study is aimed to develop and evaluate robust techniques in the fixed effect linear panel data model. The existing robust procedure normally begins with centering the data in every time series by the median. The procedure provides robustness with a drawback of producing nonlinearity to the resulting data. In this study, a different centering approach is proposed by considering M-centering. Robust coefficients of the parameters are estimated by the newly proposed robust estimator called Within MM. The performance of the robust Within MM is evaluated and compared with the existing robust Within GM estimator and the classical Within Group estimator. Extensive simulation studies are carried out at different combinations of contamination levels and outlier locations. Performances of the robust estimators are also examined using different panel sizes and centering procedures. The simulation results showed that the M-centering procedure has substantially improved the robust parameter estimates especially for small datasets. Under the M-centering, both Within MM and Within GM are able to produce resistant results to high leverage points. Although Within GM estimator consistently outperformed the newly proposed Within MM estimator, the Within MM offers the advantage of low computational load. Overall results indicated that the Within MM is able to provide a robust alternative to the classical Within Group in the presence of outliers. The parameter estimates become more robust, reliable and efficient under the proposed M-centering. Illustrations made on two numerical examples of real macro panel data sets also proved that the centering procedure can provide stability to the panel data parameter estimation.

Keywords: Panel data, Linear regression, Fixed effect model, Robust, Outliers.

OR-W1 Wednesday 10:30 – 12:00

Minimizing Total Earliness and Tardiness on Parallel Machines Using a Multi-Agent System
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[2]Department of Statistics and Operations Research, Kuwait University.

Abstract. This paper focuses on scheduling jobs with different processing times and distinct due dates on parallel machines with no inserted idle time as to minimize the sum of total earliness and tardiness. This scheduling problem is a very important and frequent industrial problem that is common to most just-in-time production environments. This NP hard scheduling problem is herein solved using an agent-based approach A-B. A-B, which is pseudo-parallel and stochastic, uses the simplest system of artificial life. This system consists of active agents dynamically interacting in real time to jointly schedule jobs on the machines while each agent is driven by its own parameters, decision process, and fitness assessment. Our computational investigation shows that A-B is particularly fast and solves very large problems.

Keywords: Scheduling, combinatorial optimization, agent-based systems, artificial intelligence, earliness, tardiness, parallel machines.

Flowshop Scheduling Problem with Maximum Lateness Criterion
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Abstract. This study addresses a two-machine flowshop scheduling problem to minimize maximum lateness where processing times are random variables with lower and upper bounds. This problem is NP-hard since the corresponding deterministic problem is known to be NP-hard. Hence, we propose nine heuristics which utilize due dates and the lower and upper bounds on job processing times along with the Earliest Due Date sequence. Furthermore, we propose an algorithm which yields four heuristics. The proposed fourteen heuristics are compared with each other and with a random solution through randomly generated data. Four different distributions (uniform, negative exponential, positive exponential and normal) of processing times within given lower and upper bounds are investigated. The computational analysis has shown that one of the proposed heuristics performs as the best over all the considered parameters and for the four distributions with an overall average percentage error of less than one.

Keywords: Random processing times, flowshop, maximum lateness, scheduling.

Scheduling in Stochastic Bicriteria Single Machine Systems with Quadratic Cost Functions
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Abstract. This paper is concerned with a single machine scheduling problem in which job related attributes are arbitrary random variables. The objective is to determine an optimal schedule that minimizes the expected cost of a quadratic cost function of two performance criteria associated with the schedule. The proposed problem is NP-hard to solve; however, special cases are solvable for some interesting criteria. These cases are equivalently formulated as quadratic assignment problems whose solutions yield the optimal schedules. Since the quadratic assignment problem is also NP-hard, we utilize some heuristics to approximate the solution. Extensive computational results are reported to evaluate the quality of such solutions. We also show that the proposed problem is general in the sense that its special or limiting cases reduce to some new stochastic and deterministic models.

Keywords: Bicriteria; Scheduling; Stochastic; Single machine; Quadratic function.

STAT-W2A Wednesday 12:15 – 13:30

Approximating the Tail Probabilities of the Trimmed Longest Run Test of Symmetry
Ayman Baklizi

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Abstract. Assume that we have N independent observations from a continuous distribution with known median. We want to test whether the distribution is symmetric about its median. Various symmetry tests are proposed in the literature. Baklizi (2007) "Testing Symmetry Using A Trimmed Longest Run Statistic. The Australian and New Zealand Journal of Statistics, 49, 4, 339- 347" introduced a test based on a trimmed longest run statistic in a suitably defined sequence of Bernoulli trials. The test was shown by simulation to have a performance at least about that of its competitors. However, the distribution of this test statistic does not have a simple closed form. In this paper we shall consider various approximations of the tail areas of this test statistic and compare their performance.

Keywords: Symmetry, Runs Test, Asymptotic Approximation.

Inferences on stress-strength reliability from Lindley distributions
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Abstract. This paper deals with the estimation of the stress-strength parameter $R = P(Y < X)$ when X and Y are independent Lindley random variables with different shape parameters. The uniformly minimum variance unbiased estimator has explicit expression, however, the exact or asymptotic distribution of it is very difficult to obtain. The maximum likelihood estimator of the unknown parameter can also be obtained in explicit form. We obtain the asymptotic distribution of the maximum likelihood estimator and it can be used to construct confidence interval of R. Different parametric bootstrap confidence intervals are also proposed. Bayes estimator and the associated credible interval based on independent gamma priors on the unknown parameters are obtained using Markov Chain Monte Carlo method. Different methods are compared using simulations, and one data analysis has been performed for illustrative purposes.

Keywords: Lindley distribution; Maximum likelihood estimator; Uniformly minimum variance unbiased estimator; Prior distribution; Posterior analysis; Credible intervals.

Statistical inference of multivariate weighted Weibull distributions
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Abstract. In this paper, we introduce a univariate weighted Weibull distribution which is obtained as a hidden truncation model. Also, we extend the proposed model to the multivariate case with weighted Weibull marginals. We propose an EM algorithm to compute the maximum likelihood estimators of the unknown parameters. One trivariate data set has been analyzed for illustrative purposes and it is observed that the proposed model and the EM algorithm both work quite well in this case.

Keywords: Hidden truncation model; Maximum likelihood estimator; Failure rate; EM algorithm; Bootstrap confidence intervals.

STAT-W2B Wednesday 12:15 – 13:30

Prediction Limits for the INAR(1) Process
Khreshna Syuhada and Abdulhamid Alzaid

Institut Teknologi Bandung – Indonesia and King Saud University, Saudi Arabia.

Abstract. We consider the problem of finding prediction limits for future observations in the stationary first-order non-negative integer-valued autoregressive or INAR(1) process. Assessment of these limits is carried out by calculating their coverage probability conditional on the last observation. Furthermore, we show the properties of the maximum likelihood estimator for parameters of the Poisson INAR(1) process.

Keywords: Coverage probability, estimative prediction limit, improved prediction limit.

Modelling wear degradation in cylinder liners
Fernanda D'Ippoliti and Fabrizio Ruggeri

University "Gabriele D'Annunzio", Pescara, and CNR IMATI, Milano, Italy.

Abstract. We present and discuss a stochastic model describing the wear process of cylinder liners in a marine diesel engine. Our interest is motivated by actual data, provided by a leading Italian ship company, operating freight and passengers ships, both in Europe and overseas. The interest in the liner wear arises since it is one of the major factor in determining failure of heavy-duty diesel engines, which are used in ships and are requested to have high reliability and availability levels. In high power diesel marine propulsion engines maximum wear usually occurs in the top region of the cylinder liner,

which is subject to high thermomechanical and tribological stresses that produce relevant early local damages.

According to many studies on diesel engine wear, it seems that the major wear in this region is caused by the high quantity of abrasive particles on the piston surface, occurring by the combustion of heavy fuels and oil degradation (soot). The soot abrasive wear mechanism acts when the lubricant film thickness is less than the soot particle size, so that the soot is involved in a three-body abrasive action with the liner metal surfaces on one side and the piston surface on the other. The wear of the liner occurs because the soot particles are harder than the corresponding engine parts. In addition to abrasive wear, a corrosive wear has also been observed, and it is due to sulphuric acid, nitrous/nitric acids and water. Physical considerations lead to identify a unique place in the liner, called Top Dead Center, in which almost all failures occur once wear exceeds a specified threshold. Therefore, measurements are performed using a micrometer near the Top Dead Center. The paper presents a stochastic model about the time evolution of the wear process of the cylinder liners of marine naval diesel engines. The model is based on a stochastic differential equation and Bayesian inference is illustrated. The model can be used to perform condition based reliability estimation and to plan condition based maintenance activities. As soon the predicted probability of a given threshold wear exceeds a given level at some future time t, then the ship are to be stopped and inspected to check the actual wear. The relevant economic aspects are about the costs of stopping ships for inspection and change of the huge liners (approximately 10 meters high) and the warranty clauses which make the ship owner responsible when failures occur when the wear exceeds a threshold, set at 4 millimeters. In the paper, we concentrate on the mathematical aspects of the model, and on the motivations leading to the model and its critical discussion. Full details are provided on the choice of the prior distributions and the MCMC scheme which allows computation of posterior quantities of interest and forecasts.

Keywords: Bayesian inference; Condition based maintenance; Markov chain Monte Carlo; Stochastic differential equations.

A Novel Application of Data Envelopment Analysis (DEA) in Marketing Research
Reza Farzipoor Saen

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Abstract. Selecting the best mode of entry for a particular foreign market is one of the most critical decisions in marketing research context. The objective of this paper is to propose a data envelopment analysis (DEA) model for selecting the best mode of entry. A real case study demonstrates the application of the proposed method.

Keywords: Data envelopment analysis, Mode of entry, Marketing research.

OR-W2 Wednesday 12:15 – 13:30

Global Optimization: Models, Algorithms, Software, and Applications
Janos D. Pinter

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Abstract. Global optimization (GO) is aimed at finding the best solution of nonlinear decision models, in the possible or verified presence of multiple optima. Traditional local nonlinear optimization methods will often fail to find the global minimum or maximum of multimodal functions. GO is an emerging area of research, with significant existing and potential applications.

We briefly review the basic concepts and methods of traditional nonlinear programming (NLP). Next, we discuss the relevance of global optimization in practical applications and formulate a canonical GO model. We then review the key GO model types, and the most prominent exact and heuristic algorithmic solution approaches. We devote a more detailed discussion to several key exact deterministic and stochastic solution strategies.

This discussion is followed by a review of modeling environments and software for solving GO problems. We introduce several professional software implementations, available for C and Fortran compiler platforms, spreadsheets, optimization modeling languages (AIMMS, AMPL, GAMS, MPL), and for the integrated technical computing systems Maple, Mathematica, and MATLAB.

The illustrative GO model examples presented include standard tests from model libraries, some well known optimization challenges, and a number of practically motivated examples. We will also review several advanced applications and case studies.

Offering the Best Interest Rate in Marketing Activity Using OR
Asaf Shupo

Bank of America, Canada Card Services, Ottawa, Canada.

Abstract. Taking care of customers and serving them better by building strategies which meet more of their financial needs is one of the most important work to maintain existing customers. In the current new environment, customers are saving more and becoming more resourceful in finding new ways to save. Building optimal marketing strategies which helping customers achieving their goals, are strongly related on the two problems: (i) defining the promotional interest rates which are specifically relevant to individual customer needs and (ii) offering the best interest rate to each customer in a profitable manner and fit naturally with the customer values. Due to these problems, new suite models were developed in conjunction with line of business using a price elasticity methodology at the customer level versus the straight response propensity model in use that did not take the customer's price sensitivity into account. The new models consider additional factors such as price sensitivity, response rate, and dollar volume.

The associated complexity of the problem, taking into account that there are hundred millions of customers and tens of products and services to offer, is mainly related to its size and integrality of the solution. In this context, it is increasingly important to find methods which are robust enough to solve large scale problem. As such, it is motivated to search for an integer optimal solution of the problem using network optimization instead of general linear programming methods. To this end, features of minimum cost flow algorithm (MCF) such as robust implementations and able to solve even large-scale problems make MCF preferable method to solve the problem. The suite of cash models, as pointed out above, aims to provide for each customer and each interest rate the probability of response and cash volume relevant to this interest rate. Our contribution is a model using MCF which when the above data are available at customer-level, the model defines which interest rate to offer to which customer in order to optimize some objective function.

In summary, the model provides an integer optimal solution which offers each customer the appropriate interest rate and optimizes the total "profit". In order to measure the quality of the solution produced by the new optimization method and new suit models versus existing approach that utilized response models and some prioritize rules, a test phase was built by splitting the population randomly 50% for each method. The improvement of using optimization process as opposed to the old approach was obvious.

The new optimization method was built with the goal to offer the best interest rate to each customer in a profitable manner. It also has the future ability to goal seek to business objectives such as optimizing total profit by considering other products and services, marketing budget optimization, and ultimately optimizing the profitability of the all marketing strategies. This functionality will be considered in future work.

Keywords: Network Optimization, Minimum Cost Flow, Marketing Strategy, Market Segmentation, Modeling .

A New Set of Algorithms to Solve Large-Scale Multi-Objective Integer Programming

Problems with Fuzzy Variables
Hossein Abdollahnejad Barough

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Abstract. Allocating resources to competing projects is typically driven by multiple quantified objectives generated from the top-level goals of a large-scale system. Analytical tools to aid such allocations have a significant history with many existing methodologies, particularly for optimization and programming within a hierarchy of objective functions. However, the quantified objective functions are known to only partially represent the system goals. In particular, the patterns of allocation of resources across the goals may be important to decision-makers, since they could address known quantifiable issues with some considerations of unknown and emergent issues. In this paper, the author presented a new set of algorithms to solve multi-objective integer programming problems with stochastic variables and independent constraints in which coefficients and right-hand side numbers are triangular fuzzy numbers. Since the problems considered in this paper are large scale and large scale problems often have special structures called block angular structure, the author proposed a new set of algorithms to solve these problems based on the decomposition algorithm developed by the weighting and the Branch and Bound methods. During each stage of these algorithms, a number of single integer programming problems are solved heuristically. The proposed algorithms are illustrated through numerical examples to clarify the method and the set of algorithms. The applications of this research are then developed and used as one of the Decision Support System models in Kayson Co.

Keywords: Multi-Objective Programming, Integer Programming, Large-Scale Programming, Fuzzy Linear Programming (FLP), Heuristics.

STAT-W3 Wednesday 14:30 – 16:00

Zero Truncated Compound Binomial-Exponential Distribution
Abdulhamid A. Alzaid[1] and Najla M. Binqurmalah[2]

[1]King Saud University, Riyadh, Kingdom of Saudi Arabia.
[2]Princess Nora Bint Abdul Rahman University, Riyadh, Kingdom of Saudi Arabia.

Abstract. In this paper, we study the zero truncated compound binomial-exponential distribution. It enjoys the most important distributional properties such as strong unimodality and stochastic monotonic properties in some of its parameters. Estimation of the parameters is discussed. A simulation study is carried out to evaluate the goodness of fit of the distribution. Three real-life data examples from different fields are used to assess the performance of the distribution.

Keywords: Binomial; Exponential; Unimodal distribution; Stochastic order; Insurance**.**

The Exact Distribution of the Sum of Two Correlated Chi-Square Variables
Anwar H. Joarder and M. Hafidz Omar

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Abstract. The exact distribution of the sum of two chi-square variables is well known if the variables are independent. We derive the exact distribution of the sum of two correlated chi-square variables when they are correlated through a bivariate chi-square distribution. The distribution is important in estimating common variance of a bivariate normal population. The graph of the density function is presented. Some properties of the distribution, namely, the characteristic function, cumulative distribution function, raw moments, mean centered moments, coefficient of skewness and kurtosis are derived. If the results of the paper are specialized to the uncorrelated case, then they, as expected, match with that of the independent case.

Keywords: Bivariate distribution; bivariate chi-square distribution; correlated chi-square variables; sum of correlated chi-square variables; characteristic function; cumulative distribution function.

Recursive Estimation of a Hidden Markov Time
Lakhdar Aggoun

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Abstract. There are many situations where one is interested in the occurrence of some specific event in scientific studies in medicine, demography, biology, sociology, econometrics, finance, etc. In this paper, using the techniques discussed in [2, 1] we estimate the probability of occurrence time of some event of interest viewed as a Markov stopping time with respect to the history generated by a hidden Markov chain.

OR-W3 Wednesday 14:30 – 16:00

Shopping path pattern analysis in a grocery store
Seung Joon Yang and Young S. Kwon

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Abstract. This study is to explore the shopping path pattern in a grocery store using RFID technology and clustering method. To do this, we attached RFID tags and readers attached to shopping carts and gondola to capture the customer purchase and travel behaviors in a grocery store. We design the appropriate distance between RFID readers to avoid the interference. Using the RFID data obtained when a customer moves along an aisle in a grocery we conduct clustering analysis. To handle the spatial nature of shopping path, we propose the variable length clustering and dijkstra approach. We can obtain several patterns of customer shopping paths in a grocery which could be used for the layout of products and gondola. Through this analysis, we can also recognize the average time customers spent in front of a certain product in a store, dead zone and hot spot, degree of the congestion in an aisle, as well as deployment plan of the store personnel at a certain time.

Keywords: Customer behavior, RFID, RFID System, Data Mining, Moving Path, Pattern Analysis, Clustering.

Modeling and Simulation of Maintenance Operations at Kuwait Public Transport Company
Mehmet Savsar

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Abstract. In this study, a simulation model is developed to analyze and improve maintenance operations of a bus fleet by Kuwait Public Transport Company (KPTC). Maintenance of its bus fleet has been one of the major problems at KPTC. About 600 buses are operated daily by the company on 40 different routes for public transportation in Kuwait. Frequently these buses fail and need corrective maintenance in addition to regular preventive maintenance activities. The company has two maintenance locations: One is in Sabhan, which handles 349 buses and the other is in Sulaibiya, which handles 248 buses. Because excessive delays occurred in the maintenance facility at Sabhan location, it was analyzed in detail and a simulation model was developed for the system to study

effects of several possible maintenance strategies on its performance. In particular, data was collected and the current maintenance system was simulated. After validation and verification of simulation results, the model was then used to simulate and analyze the system under different maintenance strategies and repair policies. The simulation results are incorporated into a cost model to evaluate each maintenance strategy and its effect on total cost. Finally, the best policy is selected based on minimum cost. The results show that substantial savings can be achieved by using an appropriate maintenance policy.

Keywords: Maintenance, Simulation, Bus Failures, Public Transportation, Repair Policies.

A new mathematical model for multi-depot vehicle routing problem
Abtin Bustani, Hamed Rafiei, Masoud Rabbani and Mehrdad Ziaee nejad

University of Tehran, Iran.

Abstract. This paper addresses a novel version of the well-known vehicle routing problem. The proposed model includes multi-depot network with customers. The customers are defined in such a way that simultaneous pickup and delivery needs are to be met by the fleet. To the best of authors' knowledge, the presented model in this paper is the first model which considers the aforementioned assumption in vehicle routing problem. The model mimics the real world conditions. In order to validate feasibility and applicability of the proposed model, some test problems are designed. Finally, some concluding remarks and future research directions are provided.

Keywords: Vehicle routing problem; Multi-depot; Simultaneous pickup and delivery; Flexible depot assignment; Split service.

STAT-TH1 Thursday 10:30 – 12:00

Interim Monitoring of Clinical Trials: Decision Theory, Dynamic Programming and Optimal Stopping
C. Jennison

University of Bath, Bath, UK.

Abstract. It is standard practice to monitor clinical trials with a view to stopping early if results are sufficiently positive, or negative, at an interim stage. We shall explain how properties of stopping boundaries can be calculated and how boundaries can be optimised to minimise expected sample size while controlling type I and II error probabilities.
Constraints on error probabilities complicate this optimisation problem. However, a solution is possible through consideration of unconstrained Bayes decision problems which are conveniently solved by dynamic programming. This conversion to an unconstrained problem is equivalent to using Lagrange multipliers. We shall present details of numerical computation for group sequential tests and their optimisation for particular criteria. We shall discuss a variety of applications in clinical trial design including the derivation of optimal adaptive designs in which future group sizes are allowed to depend on previously observed responses; designs which test both for superiority and non-inferiority; and group sequential tests which allow for a delay between treatment and response.
Since optimality in the unconstrained problem can be expressed as a sample path property, this is an "optimal stopping" problem in the language of probability theory. The computational methods we describe are, therefore, applicable to such problems, in particular, to optimal stopping problems arising in financial mathematics.

Keywords: Clinical trial, group sequential test, efficiency, Bayes decision problem, dynamic programming, optimal stopping.

Self-Similar Processes in Modeling Financial Market Volatility
Edward W. Sun

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Abstract. Several studies find that the return volatility of stocks tends to exhibit long-range dependence, heavy tails, and clustering. Because stochastic processes with self-similarity possess long-range dependence and heavy tails, it has been suggested that self-similar processes be employed to capture these characteristics in return volatility modeling. In this paper, we find using high-frequency data that German stocks do exhibit these stylized facts. Using one of the typical self-similar processes, fractional stable noise, we empirically compare this process with several alternative distributional assumptions in either fractal form or I.I.D. form (i.e., normal distribution, fractional Gaussian noise, generalized extreme value distribution, generalized Pareto distribution, and stable distribution) for modeling German equity market volatility. The empirical results suggest that fractional stable noise dominates these alternative distributional assumptions both in in-sample modeling and out-of-sample forecasting. Our findings suggest that models based on fractional stable noise perform better than models based on the Gaussian random walk, the fractional Gaussian noise, and the non-Gaussian stable random walk.

Keywords: Fractional stable noise; Fractional Gaussian noise; Heavy-tail distributions; Long-range dependence; Self-similarity; Volatility modeling.

Challenges in Modelling and Experimental Design Strategies in Dose Response Settings
Timothy E. O'Brien

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Abstract. Researchers often find that nonlinear regression models are more applicable for modelling various biological processes than are linear ones since they tend to fit the data well and these models and model parameters are more scientifically meaningful. These researchers are often in a position of requiring optimal or near-optimal designs for a given nonlinear model. A common shortcoming of most optimal designs for nonlinear models used in practical settings, though, is that these designs often have only 'p' support points, where 'p' is the number of unknown model parameters. Researchers typically desire designs which are near-optimal but which contain "extra" design points which can be used to test for model adequacy.
This talk overviews five so-called "robust" design strategies (Q-optimality, a discrimination -estimation procedure, model nesting, a general departures criterion, and a geometric design procedure) introduced by the author and others over the past several years. These design strategies will be discussed and illustrated in the context of the author's original research applications (agricultural/environmental), as well as in the contexts of chemical engineering, AIDS modelling from mother to child, and population pharmacokinetic modelling.

Keywords: curvature; differential geometry; geometric dilution designs; nonlinear regression; optimal design; robustness.

OR-TH1 Thursday 10:30 – 12:00

Linear programming with interval data: A two-level programming approach
Chiang Kao

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Abstract. Linear programming has been widely applied to solving real world problems. The conventional linear programming model requires the parameters to be known constants. In the real world, however, the parameters are seldom known exactly and have to be estimated. This paper discusses the general interval linear programming problems where all the parameters, including the cost coefficients, requirement coefficients, and technological coefficients, are represented by interval data. Since the parameters are interval-valued, the objective value is interval-valued as well. A pair of two-level mathematical programs is formulated to calculate the lower bound and upper bound of the objective values of the interval linear program. The two-level mathematical programs are then transformed into one-level nonlinear programs. Solving the pair of nonlinear programs produces the interval of the objective values of the problem. An example illustrates the whole idea and sheds some light on interval linear programming.

A New Multi-Step Diagonally Newton Method for Large Scale Systems of Nonlinear Equations
M.Y. Waziri, W.J. Leong and M.A. Hassan

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Abstract. There has been a great deal of interest to reduce computational cost, matrix storage requirement and CPU time of Newton method for solving large scale systems nonlinear equations, because of its fast convergence. In this paper, we continue in the spirit of Newton method, to develop an alternative approximation to Jacobian inverse into diagonal matrix via multi-step approach. In our approach we do not need to compute the Jacobian at all. The convergence of the method has been proven under standard assumptions. The new scheme was implemented on some benchmark nonlinear systems which show that the proposed method is very encouraging and reliable.

Keywords: multistep, Newton method, Jacobian, Optimization, diagonal and Matrix storage.

Returns to scale and set-valued scale elasticity in the presence of time factor

Majid Soleimani-damaneh

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Abstract. Dynamic Data Envelopment Analysis (DEA) measures the overall efficiency of decision making units in the presence of time factor (see Sueyoshi and Sekitani 2005). Two concepts which play a vital role in theoretical and applied DEA are returns to scale (RTS) and scale elasticity (SE). Although there are many publications addressing RTS and SE in static DEA (See Banker et al. (2004) and Soleimani-damaneh et al. (2006, 2007) among others), there is only one article in the literature on RTS in dynamic DEA: Sueyoshi and Sekitani (2005).
 In this paper we provide some theoretical and applied results on two concepts RTS and SE in DEA in the presence of time factor using dynamic DEA framework. Some basic definitions are given and their properties are established. It is shown that the SE in the presence of time factor is a set-valued map with respect to some parts of the optimal solutions of the multiplier models. A theoretical discussion about degree of homogeneous of this set-valued map in input/output space is given. Also, some relationships between SE, RTS and other notions existing in dynamic DEA are proved. Finally an application of the obtained results is provided.

Keywords: Dynamic DEA, Returns to Scale, Scale elasticity, Linear Programming, Set-valued map, Convex analysis.

STAT-TH2 Thursday 12:15 – 13:30

Challenges in Statistics and Operations Research

Adekunle Umar

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Abstract. "That was such an intense derivation of the scientific concept". This is usually the first response after a hectic session of a scientific proof. The question of data and employing statistical methodologies surfaces. In addition, along the line then comes the question of the relevance of such a proof to real–life applications.
The problems facing Statistics and Operations Research form a critical mass which impedes the hinge of national development. Therefore, ameliorative plans of action demand that relevant, functional, uncomplicated structures be put in place. Such plans of action could include the mainstreaming of statistical information strewn over a number of databases (usually different establishments) for an effective critical path analysis.
With today's ubiquitous and ever advancing technology, incidences where insufficient data could be fed into a complex analytical Operations Research (O.R.) model or in other cases where redundant data face a substandard analytical model exist. Rigorous personnel development in Statistics and O.R. disciplines could help unravel the said discrepancies and rectify faulty methodologies or models where necessary.
Scientific frameworks could be incorporated into relevant real-life needs from time to time. A polarized involvement of O.R. and Statistics experts in various organizations should be such that decision –making processes are influenced more readily by their findings.
These set of actions amongst others could set a reliable launch pad for all stakeholders in Statistics and Operations Research. This in turn go a long way in enhancing the quality of life in all ramifications of national development.

Keywords: development, effective, uncomplicated, real-life, rigorous, decision-making.

Guidelines for the Design and Statistical Analysis of Scientific Experiments

Mahmoud Hozayn Mahmoud

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Abstract. It is important to design scientific experiments well, to analyze the data correctly. An appropriate statistical model properly applied to data allows experimental results to be interpreted accurately and completely. In contrast, inappropriate or incomplete statistical designs can lead to inaccurate, or incomplete, conclusions that may lead to misinterpretation of the results of the study. These guidelines are provided to help scientific research workers perform their experiments efficiently and analyze their results so that they can extract all useful information from the resulting data. Among the topics discussed are simple, factorial with two and three factors, split and strip plot experiments. As well as factorial within split plot and split plot within factorial experiments for completely randomized (CRD) and/or completely randomized block designs (CRBD). Also will be discussed the size of the experiment using power and sample size calculations; screening raw data for obvious errors; selecting the suitable transformation methods using SPSS program, assumption and importance of t-test, analysis of variance (ANOVA), simple correlation and regression as parametric analysis; multi comparison means (LSD, New LSD, Duncan testes), some nonparametric testes and effective design of graphical data.

Keywords: experimental design, parametric and nonparametric testes, error pars.

Change Point Estimation of Location Parameter for Multistage processes Using Maximum Likelihood Method

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Abstract. Knowing when a process changes would simplify the search and identification of the special cause which disturbed the process. The knowledge of the change point can greatly aid the quality practitioner in identifying and removing special causes. Since, at most real-world manufacturing systems, the production of goods comprises several auto correlated stages, in this paper the problem of the change point detection for such processes is addressed. Also, the quality characteristics of the goods of these processes at each stage are correlated random variables. A First order autoregressive model is used for modeling a multistage process observations. It is assumed that step change is occurred in the location parameter of this AR(1) model. A $\bar{x}$-chart is established for monitoring the process observations with four samples in each stage. When any chart of each stage gives signal, we attempt to search the real time of the change. We propose two estimators for detection of the change point of stage and sample by using maximum likelihood method.

Keywords: Statistical Process Control, Change Point, Multistage Quality Control, Maximum Likelihood Function.

OR-TH2 Thursday 12:15 – 13:30

Resource constrained scheduling of construction projects
Yaghob Gholipour

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Abstract. Construction projects involve complex packages of interrelated activities with various Prerequisites. Resource limitations are the most important constraints that affect considerably on the project scheduling. These characteristics of construction projects demand particular scheduling techniques. The ordinary methods of project scheduling with all of the advantages could not satisfy sufficiently the restrictions or variation of the different kinds of resources.

The general resource-constrained project scheduling problem arises when a set of interrelated activities (precedence relations) is given and when each activity can be performed in one of several ways. Questions arise regarding which resource and duration set should be adopted, and when each activity should start and end to optimize the project cost. On the other hand, if there are not enough resources for concurrent activities, some activities begin immediately and others are delayed. This leads to longer project duration as well as a larger amount of project total cost. The proposed algorithm selects the best situation based upon the activity relationships, resource constraints, financial properties, etc. Resources available for completing tasks can be classified as either renewable or nonrenewable.

Unused renewable resources typically can be added to next periods, while nonrenewable resources are depleted after a certain amount of consumption. In a real construction project, both mentioned resources may be employed.

A Multi-phase ant colony optimization algorithm (MPACO) is applied. To increase the performance of the algorithm, some improvements have been made on the original algorithm. In some special cases, simultaneous start of the activities, may not lead to the minimum cost flow.

The proposed algorithm was applied on some examples. The results show the efficiency of the algorithm in decreasing the project total cost and duration under recourse constraints.

Keywords: project scheduling，project management, Ant Colony Optimization, optimum planning, resource constraint scheduling.

Using hidden Markov model to offer different project contracts:
the case of Iran Telecommunication Research Center
M S Niaei and F. Jolai

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Abstract. A hidden Markov model is proposed in this paper in order to classify prior contractors of a project-oriented organization. In this way, the organization is able to offer different contracts to the contractors based on their capabilities. A case study, a research center, is considered and the proposed model is implemented there. In addition, three schemes are developed to set different contract types for the classified contractors. The proposed model is validated by some real data in this case study. The validation has proved that the proposed model is able to classify future contractors in this organization.

Keywords: Project management, Contract management, Conditions of contract, Contractor classification.

A Genetic Algorithm Solution to a Nurse Scheduling Problem
Zahra Shahabi Kargar and Khodakaram Salimifard

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Abstract. Effective staff scheduling is critically important for many service organizations. Hospitals are service organizations which provide medical services around the clock. It is then increasingly important to have suitably qualified staff on duty, at the right time (Felici 2004; Maenhout 2008). It is also necessary to satisfy personnel preferences to reduce nurses' work stress, and minimize overwork costs.

The purpose of this study is to assign shifts and off days to ERCU nurses in order to satisfy ward personnel requirements while minimizing deviations from soft constraints. The model only considers full time nurses with same skill category who must work 44 hours a week according to their contracts. The scheduling period is one week and data (e.g. shifts and constraints) for this problem was provided by ERCU of Javad Cardiac Hospital which has 24 full time nurses and 11 beds for emergency patients. Here we have a 2-shift system (Day shift and Night shift), in which each work-shift is 12 hours and has fixed starting and ending times.

Hard constraints of this problem include coverage requirements (correct number of employees per day), maximum number of night shifts and minimum number of day shifts in a week, adequate period of rest. Also a nurse may start only one shift per day. Nurses' workload and nurses' preferences are soft constraints. In GA model of this study according to Aickelin (Aickelin 1999), the chromosome is a string of length n (number of nurses in ward) that indicates a feasible schedule of ERCU. Each gene of the chromosome represents an available nurse who works according to a shift pattern. A shift pattern is a 0-1 string of 14 elements which the first 7 elements are 7 day shifts and the second 7 elements are night shifts of a week. Each 1 in this string indicates a shift that should be done by corresponding nurse and 0 shows an off.

GA starts with initializing a random population of 500 chromosomes. Once the population is created each individual evaluated through the fitness function which is derived from hospital constraints. Other parameters used to GA model are Roulette wheel selection, one point crossover, and replacement of %10 of best chromosomes. To provide diversity in the population we implement a mutation operator. GA stops if no improvement occurs in 20 generations.

Experimental results show dramatic improvements in schedules compared with previous method. It only takes about 20 min to create a schedule which satisfies ward requirements and reduces nurse dissatisfaction and overwork costs.

SPECIAL TOPICS

Special Topics Thursday 14:30 – 16:00

Developments for Improving Collaborative Teaching and Learning in Statistics
Neville Davies

Royal Statistical Society Centre for Statistical Education (RSSCSE) University of Plymouth
Plymouth, UK.

Abstract. In this presentation I propose ways in which real data from two projects, *CensusAtSchool* (www.censusatschool.org.uk) and *ExperimentsAtSchool* (www.experimentsatschool), could be used to improve collaborative teaching and learning, statistical thinking and literacy for learners and teachers. I propose that existing databases and resources should be used in highly productive ways by coupling suggestions for accelerated experiential learning in statistics with developments in IT that enable many people to share and contribute to large electronic environments of material.

The success of *CensusAtSchool*, now run in seven countries, stems from providing motivational activities that spark in learners and their teachers' enthusiasm about many aspects of basic statistics. The heart of the project is in the real data collected about the learners and stored in more than 30 databases on the RSSCSE web site. The related project, *ExperimentsAtSchool* collects data that are produced from experiments the learners carry out in a designed environment. The data from the two projects are complementary, illustrating two important scenarios in which statistics can be a useful tool to get information and solve problems.

These two projects produce easily accessible archival data that have been produced by well-defined activities. I propose some new directions for the development of these projects that could form the basis of an open-source Wiki-type environment for collaborative teaching, learning and professional development activities in statistics.

The Royal Statistical Society
Gerald Goodall

Royal Statistical Society, London, U.K.

Abstract. The Royal Statistical Society (RSS) is the learned society and professional body for statistics in the UK. Although UK-based, it has a world-wide membership of around 7000. It was established in 1834 and received its Royal Charter in 1887.

As a learned society, the RSS runs scientific meetings and conferences, publishes its *Journal*, its outreach magazine *Significance*, a members newsletter and occasional special reports. It has special interest Sections and Local Groups. It recognises excellence through prizes and awards. It endeavours to influence public policy and the media regarding statistical matters. It has a lively external relations policy. It also has a general education policy; it offers activities for schools and it endeavours to influence curriculum development in schools and universities. More widely, it is embarking on a 10-year campaign to enhance statistical literacy in general.

As a professional body, the RSS confers professional status on people with approved qualifications and experience. It has a Code of Conduct for its members. It has a policy for continuing professional development.   It runs its own professional examinations. It offers training courses through its Professional Development Centre. It provides a careers advisory service, mainly through its website and through printed material.

The RSS provides a service for accrediting university courses, in the UK and overseas. The BSc courses in the Department of Statistics and Operations Research at Kuwait University are accredited by the Society.

The talk will explain in more depth the services of the Society and the benefits that it offers.