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FACULTY OF MATHEMATICS, K. N. TOOSI UNIVERSITY OF TECHNOLOGY

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Iranian Statistical Society | K. N. Toosi University of Technology

In the Name of God,
the Compassionate, the Merciful

Faculty of Mathematics
K. N. Toosi University of Technology

Abstract Booklet (English)

of the

18th Iranian Statistics Conference

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Summer 2026

Preface

By the grace of God, the 18th Iranian Statistics Conference is hosted by the Department of Computer Science and Statistics, Faculty of Mathematics, K. N. Toosi University of Technology, Tehran, on 29-31 August 2026 (7-9 Shahrivar 1405). This scientific event aims to provide a suitable opportunity for presenting the latest research achievements, fostering discussion among faculty members, researchers and statistics experts, and promoting statistical culture, data literacy and the applications of statistical science across diverse fields.

The organizing and scientific committees have made every effort to hold the conference at a high scientific standard. Under the scientific secretaryship of Dr. Mohammad Arashi and the executive secretaryship of Dr. Ahad Malekzadeh, keynote lectures, specialized sessions and contributed papers have been arranged with the support of the Iranian Statistical Society and the host university. Selected English abstracts are collected in this booklet for the benefit of the statistical community.

We sincerely thank Dr. Ali Zakeri, Dean of the Faculty of Mathematics, and all colleagues of the Faculty of Mathematics for their support. We also thank all colleagues and officials who contributed, directly or indirectly, to the organization of the conference: the presidency and vice-presidencies of K. N. Toosi University of Technology, the Board of Directors of the Iranian Statistical Society, the members of the scientific and executive committees, the secretariat, the referees, the scientific and financial sponsors, and all those who assisted the conference in any way.

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Preference-Based Reinforcement Learning and Adversarial Robustness

Maryam Abdolali[1]

Department of Mathematics and Computer Science, K.N.Toosi University of Technology

Abstract: Preference-based reinforcement learning has become a central approach for training agents when rewards are difficult to specify directly. Instead of relying on hand-designed reward functions, these methods learn from comparisons, rankings, or other forms of human preference feedback. This idea is also central to reinforcement learning from human feedback, which has been widely used to align large language models and other interactive systems with human judgments. However, preference feedback is not always reliable: labels may be noisy, inconsistent, biased, or even adversarial. In practice, different annotators may have different levels of expertise, interpret the task differently, or provide systematically misleading feedback. If such labels are treated as equally trustworthy, they can distort the learned reward model and negatively affect the behavior of the trained agent. This presentation introduces the basic motivation and workflow of preference-based RL and RLHF, then focuses on the problem of adversarial robustness. In particular, it discusses how learning systems can detect, downweight, or correct misleading preference labels, and why robust treatment of annotators is important for building safer and more reliable aligned agents.

Keywords: Preference-based reinforcement learning, reinforcement learning from human feedback, reward modeling, adversarial robustness.

Mathematics Subject Classification (2010): 68T05, 68Q32, 62F35.

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Graph Feature Extraction for Path Planning Using Machine Learning by SVM and GNN

Mohsen Abdolhosseinzadeh[1] , **Hojjat Emami**[2], **Babak Azarnavid**[3]
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[2]**Department of Computer Engineering, University of Bonab, Bonab, Iran**

Abstract:

This paper surveys how machine learning, particularly graph neural networks and transformer architectures, automates the extraction of features to improve path planning processes. We characterize the methodological development from traditional topological invariant graph features to advanced data-driven representation learning frameworks, demonstrating their efficacy in optimizing navigation policies across complex, stochastic, and multi-agent operational domains. Furthermore, the practical realities of implementing these models are addressed, focusing on computational limits at the edge, real-world execution, and enhancing models in operational settings. Finally, experimental results are provided supporting the efficacy of the proposed graph feature extraction framework in reducing node expansions and improving path optimality across a variety of path planning benchmarks.

Keywords:
Path planning, Graph Neural Networks, Heuristic learning, Problem reduction.

Mathematics Subject Classification (2010): 68T20, 68T05, 90C27.

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Bayesian Optimal Design for Exponential-Shift Regression Model with stick breaking method and uniform distribution as the base measure

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[2]**Faculty of Mathematics, Lahijan University, Lahijan, Iran**

Abstract:
In this study, we initially present the shifted exponential regression model and then derive its corresponding optimal experimental designs by employing the Dirichlet Process (DP) as a prior distribution over the parameter space. The resulting optimal design problem is formulated as a nonlinear optimization task, and the final solutions are obtained using the `Rsolnp` package implemented in the `R` statistical computing environment.
Keywords: Exponential-Shift Regression, Lifetime Data Analysis, Reliability Modeling, Nonparametric Bayesian Optimal Design, Dirichlet Process.
Mathematics Subject Classification (2010): 60E05, 60Exx.

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Analysis of social network Facebook comments using ML, Deep Learning, and lexicon-based

Sheyda Abdolmakeki[1,2], Vadood Keramati[1]
[1]**Allameh Tabataba'i University, Tehran, Iran**

Abstract:
Customer satisfaction is the most important tool for understanding how our application works. Facebook is one of the most popular applications in the world that most people use. Hence, analyzing the comments in the application is useful for knowing its performance. The analysis was conducted using a series of specialized functions commonly employed in these methods to evaluate people's opinions and sentiments toward the program. The opinions and sentiments are classified into 4 classes (natural, positive, negative, and empty). In the end, the results of the two methods were compared to determine which method performed better for data analysis.
Keywords: Sentiment Analysis,Machine learning,deep learning,Lexicon-based
Mathematics Subject Classification (2010): 99X99, 99X99, 99X99.

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Enhancing Decision Tree Learning via Conditional Cumulative Residual Entropy: A Framework for Continuous Variables

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Abstract:
Conventional decision tree algorithms struggle with continuous variables, often causing information loss through discretization. This paper proposes a novel framework using Conditional Cumulative Residual Entropy (CCRE) to directly handle continuous inputs and outputs. Unlike traditional entropy measures, CCRE provides a more nuanced uncertainty measure for continuous distributions. The theoretical framework for the splitting criterion is derived, and its effectiveness is shown across regression and classification tasks. Empirical evaluations indicate that this approach eliminates discretization biases and yields superior predictive performance compared to baseline methods. The results highlight CCRE's potential as a powerful tool for tree-based learning, contributing significantly to data mining and machine learning.

Keywords: Conditional Cumulative Residual Entropy, Decision tree, Machine learning
Mathematics Subject Classification (2010): 99X99, 99X99, 99X99.

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Multilevel Analysis of Misclassified Binary Outcomes: Validation-Data-Based Approach Adjusting for Covariate Measurement Error

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Abstract:
Longitudinal designs inherently involve correlated repeated measurements nested within individuals. In such frameworks, time-varying covariates and discrete response variables are frequently subject to error due to methodological constraints or prohibitive costs. Naive estimation strategies that ignore errors in either the covariates or the response, systematically yield biased parameter estimates, affecting the validity of statistical inference and reducing asymptotic efficiency. To address this, we propose a joint modeling framework that simultaneously adjusts for misclassification in correlated binary responses and measurement error in continuous covariates. Our methodology leverages validation data to reliably estimate the misclassification mechanism and employs multivariate Gauss-Hermite quadrature to approximate the intractable integrals within the marginal likelihood function. Simulation studies are conducted to evaluate the finite-sample performance of the proposed estimator.
Keywords: Measurement Error, Internal Validation Data, Multivariate Gauss-Hermite Quadrature, Random Effects Logistic Regression Model, Misclassification.
Mathematics Subject Classification (2010): 62J12, 62F10.

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Grey Relational Analysis: A Statistical Approach to Measuring Dependence in Data-Poor Conditions

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Abstract:
Grey relational analysis is one of the most important tools in grey systems theory that is used to measure the intensity of the relationship between variables in situations where data are limited, incomplete, or uncertain. In terms of functionality, this method is similar to some statistical methods such as correlation and dependence analysis, but unlike classical statistics, it does not depend on strict assumptions such as normality of distribution, large sample size, or linearity of the relationship. Grey relational analysis, by focusing on the similarity of the pattern of changes between data series, allows ranking of effective factors and identifying important variables. In this article, the theoretical foundations, formulation, implementation steps, its connection with statistical concepts, and its applications in data analysis are reviewed.
Keywords: Grey relational analysis, grey statistics, statistical dependence, correlation, incomplete data, factor ranking.

Mathematics Subject Classification (2010): 62H20, 62H25, 62G99.

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A Density-Augmented Representation Framework for Improving Clustering of Nonlinear Synthetic Data

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Abstract:

Clustering performance may deteriorate when nonlinear geometry, heterogeneous local density, or outliers make the original feature space insufficiently informative. This paper proposes an Adaptive Hybrid Density-Augmented Clustering (AHDC) framework that enriches standardized original features with local density-based descriptors and controls the contribution of the density-feature block through an observation-specific adaptive weight. Experiments on five synthetic datasets over 20 runs show that AHDC achieves its largest observed gain for nonlinear structures, while its mean ARI remains close to that of raw-feature K-means in the Easy, Hard, and Outlier scenarios. Its performance decreases under strong cluster-size imbalance, where K-means Raw and Spectral clustering achieve higher mean ARI values. These findings indicate that adaptive density augmentation is beneficial under specific geometric conditions rather than uniformly superior across all clustering regimes.

Keywords: adaptive clustering, density-aware representation, adaptive feature fusion, neighborhood-based features, nonlinear clustering.

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A $1/2$-Hölder continuous diffusion coefficient driven by G-Brownian motion

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Abstract:
G-Brownian motion refers to a type of Brownian motion with uncertain variance, where the variance takes values within a compact interval rather than being a fixed discrete value. In this paper, we investigate a $1/2$-Hölder continuous diffusion coefficient driven by G-Brownian motion, which can be applied to model interest rates, stock prices, stochastic volatilities, or default times under model uncertainty. We investigate the existence and uniqueness of the quasi-surely non-negative solution. Furthermore, certain features of the solution are pointed out, including regularity with respect to the initial time and initial value and the strong Markov property.
Keywords: Model uncertainty, $1/2$-Hölder continuous diffusion coefficient, G-Brownian motion
Mathematics Subject Classification (2010): 60H10, 60H30.

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Bayesian variable selection under empirical likelihood for AFT models in high-dimensional censored biomedical data

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Abstract:
Bayesian variable selection in high-dimensional accelerated failure time models is particularly challenging in the presence of heavy censoring, multicollinearity, and heterogeneous effect sizes, settings in which the regularity conditions required by standard empirical likelihood methods may fail. We propose a unified Bayesian empirical likelihood framework for semiparametric AFT regression based on a robust estimating equation. The framework jointly addresses regularization, variable selection, and posterior computation. A Buckley-James estimating procedure is incorporated into a split-sample empirical likelihood construction to improve feasibility while avoiding full parametric specification of the error distribution. To achieve stable sparsity recovery in the presence of correlated predictors, we introduce a hybrid discrete-continuous prior that combines an exact point-mass spike with a horseshoe-type slab. Variables are selected using a z-cut threshold calibrated by posterior inclusion probabilities, providing a principled transition from continuous shrinkage to discrete model selection. Under suitable regularity conditions, we establish model-selection consistency and posterior consistency. An adaptive, geometry-aware Metropolis-Hastings algorithm is developed to improve posterior exploration. Simulation studies demonstrate improved estimation and selection accuracy, MCMC efficiency, and computational stability.

Keywords: Accelerated failure time, Adaptive tailored Metropolis-Hastings, Bayesian empirical likelihood, Buckley-James, Split-sample EL, Spike and horseshoe-type slab.
Mathematics Subject Classification (2010): 62J05, 62F15, 62G08.

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A Multicollinearity Diagnostic with Copula-Dependent Random Variables in Path Analysis Models

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Abstract:
IPath analysis is an extension of the multiple regression model and captures both the direct and indirect effects of exogenous variables on the endogenous variable. Sometimes, the assumption of independence is violated in several situations, and multicollinearity is present in the model. In such a situation, the model may fail to capture the significant effect of one variable on another variable. Recently, copula models have been introduced to capture complex dependence structures and address several limitations of the traditional regression approach. This work aims to study the path models when the variables are connected via elliptical copulas and multicollinearity is present in the model. A well-defined simulation study is conducted to examine the performance of path models in estimating direct and indirect effects using traditional and copula-based regression approach. A cross-validation process is applied to ensure the unbiasedness of the results. Finally, application of a real data set is presented to show the superiority of the copula approach.

Keywords: Path Analysis, Multicollinearity, Copula, Regression, Direct and Indirect Effects, 5-fold Cross Validation Technique.

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Comparative Evaluation of Regression Kriging and Smoothing Splines for Spatial Prediction of Soil Zinc Contamination

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Abstract

Accurate mapping of soil contamination is essential for environmental assessment and remediation planning. This study compares Regression Kriging (RK) and Smoothing Splines (SS) for estimating zinc (Zn) concentrations in the Meuse River Basin using distance from river as an environmental covariate. Variogram analysis indicated a strong spatial structure, with a nugget effect of 0.0356, a total sill of 0.2866, and a range of 267.3 m. Model performance was evaluated through leave-one-out cross-validation (LOOCV). The results showed that RK outperformed SS, yielding lower RMSE (RK:0.3868 vs. SS:0.3989) and MAE (RK:0.2811 vs. SS:0.2966). By integrating regression with geostatistical modeling of residuals, RK provided more accurate predictions and better identified local contamination hotspots. These findings highlight the advantage of hybrid geostatistical approaches for spatial modeling of heavy-metal pollution in river-basin environments.

Keywords: Regression Kriging, Smoothing Spline, Spatial Autocorrelation, Auxiliary Variable, Digital Soil Mapping, Soil Contamination.

Mathematics Subject Classification (2010): 62H11.

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Periodic Splines, SARIMA, and Frequency-Domain Analysis: A Comparative Study Using the Arosa Ozone Dataset

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Abstract:

Modeling seasonal patterns in long-term environmental records is one of the most demanding problems. This study compares frequency-domain harmonic regression, cyclic cubic splines, and SARIMA using the Arosa monthly total column ozone series (1926–1971, $n = 518$). Harmonic regression outperformed both alternatives across all criteria: lowest in-sample MSE (276.92), strongest cross-validation (RMSE$= 2.81$, $R^2 = 0.82$, MAPE$= 0.87\%$), and best out-of-sample forecasting (MSE≈ 7.92, MSPE≈ 2.05). SARIMA followed closely, while periodic splines lagged because the ozone cycle is nearly sinusoidal. Classical spectral methods remain hard to beat for regular seasonal patterns.

Keywords: Periodic Splines, Frequency-Domain Analysis, SARIMA, The Arosa Ozone Dataset.

Mathematics Subject Classification (2010): 99X99, 99X99, 99X99.

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Liu-type estimators for the Elliptical SUR Model

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Abstract:

This paper investigates the application of Liu estimators within the seemingly unrelated regression (SUR) model under conditions of multicollinearity and elliptically distributed errors—an issue often observed in applied economic research. The conventional SUR setup is generalized by incorporating partially linear components, which improves adaptability for intricate econometric specifications. Asymptotic characteristics of the introduced estimators are established, alongside detailed risk assessments that highlight their theoretical benefits. A wide range of Monte Carlo experiments confirms the enhanced effectiveness of this estimator relative to traditional approaches.

Keywords:

Elliptical errors, Multicollinearity, Partially linear model, Seemingly unrelated regression.

Mathematics Subject Classification (2010): 99X99, 99X99, 99X99.

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Information Loss in Spatial Statistics Analysis: Entropy, Scale, and Uncertainty

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Abstract: Spatial data often contain several layers of information that are not fully represented in final statistical summaries. A spatial field, image, disease map, or set of regional observations may include spatial dependence, local heterogeneity, scale effects, and uncertainty. In statistical practice, however, these complex structures are often reduced to estimated parameters, smoothed surfaces, clusters, risk measures, test results, or prediction errors. Such reductions are useful and sometimes necessary for interpretation, communication, and decision-making, but they may also hide important parts of the original spatial information. This talk discusses information loss in spatial statistics from an entropy-based perspective. Entropy provides a natural way to think about information, uncertainty, and reduction in spatially structured data. The aim is to examine how spatial information changes when data are aggregated, smoothed, classified, or summarized, and to highlight the role of entropy, Bayesian inference, and uncertainty quantification in understanding what is preserved, simplified, or lost during spatial statistical analysis.

Keywords: Spatial statistics, Entropy, Information loss, Spatial dependence, Scale effects, Uncertainty quantification.

Mathematics Subject Classification (2010): 62M30, 94A17, 62F15.

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Dynamic Survival Analysis of Cancer with Time-Varying Clinical Data

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Abstract:
Survival outcomes are often influenced by clinical factors that change over time, yet many existing methods rely on discrete-time approximations or restrictive assumptions. We present a continuous-time survival modeling framework for irregularly observed longitudinal data. The proposed approach captures latent disease dynamics, estimates individual risk trajectories, and supports interpretation through temporal attribution and counterfactual analysis. Using a simulated oncology cohort, we show that the framework can represent complex time-varying hazard patterns while maintaining predictive accuracy and interpretability. Latent trajectory representations also enable the identification of heterogeneous risk profiles without predefined subgroup labels. Together, these components provide a unified framework for modeling and exploring survival processes with longitudinal measurements and non-proportional hazards.

Keywords: Survival analysis, Longitudinal data, Time-varying covariates, Continuous-time modeling, Cancer risk prediction

Mathematics Subject Classification (2010): 62Nxx, 92B15, $62-07$.

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Predicting Competitive Bidding Behavior Under Uncertainty Using Scenario-Informed Machine Learning

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Abstract:
Competitive bidding behavior in project tendering is difficult to predict under market volatility and uncertainty. This study proposes a scenario-informed machine learning approach to classify bidding behavior into aggressive, moderate, and conservative strategies. Using 850 completed tenders from 2018 to 2023, three algorithms, Random Forest, Support Vector Machine, and XGBoost, were trained and evaluated through a temporal train-test split. Results show that Random Forest performs best, achieving 89.2% accuracy and an F1-score of 0.87. The number of bidders, exchange rate volatility, and past success in similar tenders are identified as the most influential predictors.
Keywords: Competitive bidding behavior; Scenario-informed machine learning; Project tendering; Uncertainty; Decision support; Random Forest.
Mathematics Subject Classification (2010): 62P30, 68T01, 90B50.

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A Cumulative Past Entropy-Based Model for Objective Weighting in Multi-Criteria Decision-Making

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Abstract:
Determining the weights of criteria is a fundamental step in multi-criteria decision-making (MCDM). Objective weighting methods are particularly attractive because they derive weights directly from the observed data and avoid subjective bias. Among the information-theoretic approaches, entropy-based methods have been widely used to capture the amount of uncertainty and dispersion associated with each criterion. However, classical entropy measures may not fully reflect the structural characteristics of data in certain decision environments. In this paper, a novel objective weighting model based on cumulative past entropy (CPE) is proposed. Motivated by these developments, we employ CPE to construct criterion weights in MCDM problems. The proposed approach first organizes the data in a decision framework, then normalizes the observations, computes the cumulative past entropy of each criterion, and finally derives the corresponding objective weights. Because the method incorporates the distributional behavior of past observations, it can provide a more informative and robust basis for weighting criteria in asymmetric or irregular datasets.
Keywords: Multi-criteria decision-making, Objective weighting, Cumulative past entropy, Shannon Entropy
Mathematics Subject Classification (2010): 99X99, 99X99, 99X99.

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Attention-Based Reinforcement Learning for Continuous Maintenance Decision-Making in Parallel Systems

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Abstract:
Predictive maintenance of parallel systems requires dynamic decision-making under uncertainty because individual units experience stochastic degradation and maintenance resources are limited. This paper proposes an attention-based reinforcement learning framework for degradation-aware maintenance scheduling in multi-unit systems. Unlike conventional approaches that optimize maintenance decisions based on fixed thresholds or individual remaining useful life (RUL), the proposed method learns a dynamic maintenance priority score for each unit and determines continuous maintenance intensities according to system-level objectives. Each unit's degradation is modeled using a stochastic Gamma process, while the reinforcement learning agent observes unit-level health indicators and jointly learns maintenance priorities and maintenance intensities under limited maintenance resources. The objective is to minimize long-term maintenance, failure, and production loss costs while improving system availability.
Keywords: Predictive Maintenance, Reinforcement Learning, Attention Mechanism, and Parallel Systems.
Mathematics Subject Classification (2010): 90B25, 68Q32.

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A Review of Smooth Estimation of the Cumulative Distribution Function under Judgment Post Stratification

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Abstract:

This paper provides a review of smooth estimation methods for the cumulative distribution function (CDF) under the judgment post stratification (JPS) sampling scheme. Particular attention is devoted to a general class of CDF estimators that encompasses both empirical and kernel-based estimators. The main finite-sample and asymptotic properties of these estimators are summarized and discussed. To further illustrate their performance, an extended Monte Carlo simulation study is conducted to compare the kernel distribution function (KDF) estimator under JPS with its counterpart based on simple random sampling (SRS). The comparison considers a range of sample sizes, set sizes, and ranking qualities. The findings demonstrate that incorporating ranking information through the JPS design can lead to considerable efficiency gains relative to SRS across a broad spectrum of settings.

Keywords: Nonparametric estimation, Monte Carlo simulation, Judgment ranking, and Statistical inference

Mathematics Subject Classification (2020): 62D05, 62G05.

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Maximum likelihood estimation of length-biased censored data under Frank copula dependency

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Abstract:
Ignoring censoring causes bias in survival analysis, especially for length-biased data. In this work, we estimate parameters in length-biased survival data with dependent censoring using a copula function to model the dependency between survival and censoring times. Extensive simulations show that our approach improves estimation accuracy and simplifies computing conditional probabilities of copulas. A real-data application is also provided.

Keywords: Survival analysis, Length-biased, Copula, Parameter estimation
Mathematics Subject Classification (2010): 62H05, 62Hxx, 62N02.

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Convergence rate of a new non-parametric change-point estimator within a linear model

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Abstract:

We study a nonparametric change-point problem in a linear regression framework under sub-exponential errors. The observations initially follow a homoscedastic linear model and undergo an unknown change after a breakpoint. Contrary to classical parametric approaches, the post-break behavior is not assumed to remain linear and may involve nonlinear perturbations or variance changes. We introduce a new penalized residual criterion for breakpoint estimation and establish consistency with convergence rates close to the optimal parametric rate up to a logarithmic factor. Numerical simulations illustrate the robustness and stability of the proposed estimator under several nonlinear and heteroscedastic scenarios.

Keywords: Change-point detection, Nonparametric estimation, Linear regression, Sub-exponential distributions, Structural break.

Mathematics Subject Classification (2010): 62G05, 62J05, 62F12.

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Enhanced Bivariate FGM Copulas for Accurate Dependency Analysis

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Abstract:

A new class of bivariate FGM copulas is proposed, extending existing models. Its properties and association measures are derived, and applications to medical data show improved correlation and tail dependence. A simulation method is developed and validated to reproduce the original dependency structure.

Keywords: FGM Copula, Measures of Dependence.

Mathematics Subject Classification (2010): 62H05, 62H20.

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More Powerful Tests for Two-Sided Sign Testing of Logistic Location Parameters

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Abstract:
In restricted-parameter testing problems, classical approaches typically do not lead to uniformly most powerful or uniformly most powerful unbiased tests. In this work, we consider a two-sided sign testing problem for the location parameters of two independent Logistic distributions under an intersection–union formulation. We derive the intersection–union test and the likelihood ratio test, show that they have the same rejection region, and adapt the rectangle and smoother tests to construct procedures that improve power while maintaining size α.
Keywords: Intersection-union test, Likelihood ratio test, Rectangle test, Smoother test, Two-sided testing.
Mathematics Subject Classification (2010): 99X99, 99X99, 99X99.

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A unified view of probabilistic inference under incomplete information: Maximum Entropy and Bayesian Updating .

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Abstract:
Statistical inference under incomplete information involves two complementary but distinct tasks: assigning an initial probability distribution when knowledge is limited to partial constraints, and updating that distribution when observations become available. Maximum Entropy addresses the first task by selecting a distribution consistent with the known moment conditions, thereby avoiding assumptions unsupported by the available information. Bayesian inference addresses the second by using the likelihood to revise prior probabilities in light of observed data. Recent work connects these roles within a single Bayesian framework: moment constraints determine the prior weighting of candidate distributions, while observations modify those weights through the likelihood. When the constraint-based prior is sharply concentrated around the entropy-maximizing distribution, the Bayesian result approaches the Maximum Entropy solution. This review examines this connection and illustrates the resulting probabilistic updating process through a numerical experiment.
Keywords: Maximum Entropy, Bayesian Inference, and Entropic Priors.

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Stochastic Hypergroups and Applications in Statistics

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Abstract:

This note gives a concise but rigorous introduction to hypergroups and stochastic hypergroups, with emphasis on their relevance to statistics. We begin with the precise axiomatic definition of a hypergroup, then introduce stochastic hypergroups as convolution structures in which each convolution product is a probability measure. We present one canonical example and one highly illustrative stochastic example, and then prove three fundamental theorems concerning convolution operators, random-walk transition kernels, and statistical estimation on hypergroup-valued data. Throughout, we follow the standard framework developed in harmonic analysis and probabilistic hypergroup theory; see, for example, **???**.

Keywords: Stochastic Hypergroups, Statistical Inference on Manifolds, Harmonic Analysis, Random Walks on Algebraic Structures.

Mathematics Subject Classification (2010): 43A62, 60B15, 62H99, 60J10

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Hypergroups-Based Modifications of a Traditional Clustering Algorithm for Heterogeneous Big Data Analytics

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Abstract:
Classical clustering models often falter when faced with the inherent heterogeneity and uncertainty prevalent in big data. This paper introduces a novel hyperalgebraic framework, specifically leveraging hypergroups, to address these challenges by fundamentally modifying a traditional clustering algorithm. We establish a robust pipeline for representing complex, multi-valued observations within this hypergroup structure. This includes developing hyper-mean and hyper-variance estimators tailored for this new representation and proving their theoretical stability. Our framework incorporates a computationally efficient hyper-fusion algorithm designed for large-scale data, demonstrating particular effectiveness in scenarios characterized by ambiguity and non-deterministic relationships. Theoretical guarantees and simulation results confirm the superior performance of our modified hypergroup-based clustering approach over traditional methods, especially in uncertain and high-dimensional data landscapes.
Keywords: Big data analytics, Hyperstructures, Hypergroups, Set-valued statistics, Multi-valued data, Statistical inference, Uncertainty quantification, Clustering, Simulation.
Mathematics Subject Classification (2010): 06F05, 60G07, 62H30, 28A80

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Fuzzy Bayesian Inference with Soft Sets

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Abstract:

This paper presents a novel framework for Bayesian inference designed to handle data characterized by inherent fuzziness and uncertainty, utilizing the expressive power of soft sets. We introduce the concept of a Soft Bayesian model, which extends classical Bayesian methodology by formally incorporating soft evidence and soft fuzzy prior information. The core of our approach lies in defining soft likelihoods and soft priors that can capture nuanced epistemic uncertainty. We provide the mathematical formulation for soft Bayesian updating, enabling the computation of soft posterior distributions.

Keywords: Soft Sets, Fuzzy Sets, Bayesian Inference, Uncertainty Quantification, Soft Likelihood, Soft Prior, Fuzzy Regression, Statistical Modeling.

Mathematics Subject Classification (2010): 62F15, 62F35, 62F99, 03E72

A Functional Beta Regression Approach for Analyzing Bounded Data with Derivative Information

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Abstract:
This paper proposes a novel partial functional beta regression model for bounded responses in $(0, 1)$. The model incorporates a functional predictor, its derivative, and additional scalar covariates, using a logit link function to model the mean of the beta distribution. We employ basis expansions and penalized maximum likelihood for estimation, capturing both global effects and dynamic behavior via the derivative term. Under standard regularity conditions, we establish the identifiability and consistency of the estimators. Simulation results and an application to near-infrared milk spectra demonstrate that integrating derivative information significantly improves predictive accuracy and provides better interpretability compared to standard functional models.
Keywords: beta regression; functional data analysis; derivative effects; penalized likelihood; NIR spectroscopy.

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Cardiovascular Diseases classification using machine learning models

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Abstract:
Early detection of cardiovascular diseases (CVD) is vital for mitigating mortality and enhancing patient outcomes. Therefore, there is a pressing need for accurate and reliable diagnostic tools. To address this, we evaluated five machine learning models for heart disease prediction: LightGBM, XGBoost, random forest, logistic regression, and a deep neural network. We applied these models to a clinical dataset comprising 1000 patient records. Our experimental results demonstrate that LightGBM achieved the best performance, with a test accuracy of 0.995, a perfect recall score, and an F1 score of 0.996. Finally, SHAP analysis identified slope, resting blood pressure, and serum cholesterol as the most influential predictors in the dataset.

Keywords: Cardiovascular diseases, Machine learning, Classification, LightGBM
Mathematics Subject Classification (2010): 68T05, 62H30, 62P10.

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A Distortion-Based Framework for Constructing New Families of Copulas and Bivariate Reliability Models

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Abstract:
Copula functions provide a powerful framework for modeling dependence structures independently of marginal distributions and have been widely applied in reliability analysis, survival studies, actuarial science, and risk management. In this paper, we propose a general framework for constructing a new family of copulas based on distortion distributions. The proposed approach starts by introducing a distorted version of an arbitrary baseline distribution through a suitable distortion mechanism. Based on the resulting survival function, a class of bivariate survival models is constructed, and the corresponding family of copulas is derived using Sklar's theorem. The proposed framework provides a systematic method for generating copula families from arbitrary baseline distributions while preserving important distributional and reliability characteristics. Several dependence properties of the resulting copulas are also investigated. The proposed family includes some existing copula constructions as special cases and extends them within a unified framework, providing a flexible and tractable approach for developing new dependence models with potential applications in reliability and survival analysis .
Keywords: Copula Function,Distortion Distribution,Bivariate Survival Model,Reliability Analysis
Mathematics Subject Classification (2020): 62H20, 62E10, 62N05.

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EndSurvGAN: End-to-End Survival-Aware Generative Modeling of Censored Time-to-Event Data

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Abstract: Generating realistic synthetic survival data remains a challenging task due to the complex dependencies among covariates, survival times, and censoring indicators. Existing approaches often rely on stage-wise frameworks that separately model feature generation and survival outcomes, potentially weakening the coherence of the underlying joint survival distribution.

In this paper, we propose **EndSurvGAN**, an end-to-end survival-aware generative adversarial network designed to jointly model covariates, survival times, and censoring indicators within a unified framework. By directly learning the joint survival distribution, the proposed model preserves both survival dynamics and censoring mechanisms during data generation.

The proposed framework is evaluated on three benchmark survival datasets, namely SUPPORT, ACTG, and Rotterdam. Experimental results indicate improved distributional fidelity, better preservation of Kaplan Meier survival curves, and enhanced downstream predictive utility compared with existing tabular and survival-specific generative models. These findings suggest that end-to-end survival-aware generative modeling provides an effective framework for synthetic censored survival data generation.

Keywords: Survival Analysis, Synthetic Data Generation, Generative Adversarial Networks, Censored Survival Data, Deep Survival Learning, Healthcare Analytics
Mathematics Subject Classification (2010): 99X99, 99X99, 99X99.

Kernel Density Weighted Twin SVM: A Robust Approach to Noisy Data

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Abstract:

We address the sensitivity of Twin Support Vector Machine variants to label noise by proposing a density-weighted Least Squares Twin Support Vector Machine (KDEWLSTSVM). The method integrates kernel density estimation (KDE) into the least-squares optimization to assign global density-based sample weights, which naturally reduce the influence of low-density and potentially mislabeled samples while avoiding graph construction used in locally weighted approaches. Experiments on three binary classification datasets with simultaneous feature perturbations and 20% label noise show that KDEWLSTSVM consistently outperforms LSTSVM and LSWLTSVM in both accuracy and overall ranking using a linear kernel. These results demonstrate that density-based weighting improves robustness and generalization under noisy conditions.

Keywords: Twin support vector machine, Kernel density estimation, Label noise robustness, and Density-based weighting.

Mathematics Subject Classification (2010): 68T10, 62H30, 62G07.

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Design and Implementation of BGSBPM Model in Business Data Evaluation

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Abstract:
Creating an ecosystem of organizational behavior and communication between different devices through data transfer is very important. In order to evaluate and predict the behavior of any business, a conceptual model is also needed to organize, analyze, and produce valid statistical reports. However, due to the lack of identical conditions among different devices or business environments, it is necessary to first declare the quality assurance of data production based on a standard approved by reputable centers such as the Statistical Center of Iran, and then carry out the next steps. However, usually for official statistics, there are characteristics including data aggregation, uncertainty, diversity, volume, speed, validity, variability, vulnerability, data value, and data security. Therefore, given the existence of the declared indicators, the important question is how to prepare reports that have the necessary validity for the data. In this study, in addition to introducing the BGSBPM model for evaluating data related to business environments, the proposed model is also used to evaluate and monitor data.
Keywords: Generic Statistical Business Process Model,Official Statistics
Mathematics Subject Classification (2010): $62-XX$.

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Randomly Constrained Shrinkage Estimator in Restricted Multivariate-t Regression Model

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Abstract:
In the restricted elliptical regression model, a new shrinkage estimator of the regression vector parameter is proposed by utilizing the restricted estimator. The approximate expressions for its quadratic risk function is derived. Numerical results indicate that the proposed shrinkage estimator outperforms the generalized least squares estimator in terms of risk, since it incorporates the prior restriction information and shrinks the unrestricted estimator toward the restricted space, thereby reducing the mean squared error when the restriction is approximately valid.

Keywords: Shrinkage estimator,Stochastic restriction,Linear regression model,Elliptical distribution
Mathematics Subject Classification (2010): 62F10, 62F03, 62H05.

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On the Probability Generating Function of Discrete Distribution Generated by Cauchy Stable Density

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Abstract:
In this paper, we study the probability generating function (PGF) of a discrete distribution induced by the Cauchy stable density, referred to as the Discrete Cauchy Distribution. An approximate analytical representation of the PGF is derived, and its asymptotic behavior is examined. The analysis shows that the PGF develops a logarithmic-type singularity in its domain, indicating that the distribution is heavy-tailed with infinite mean. These results provide a precise analytical characterization of the Discrete Cauchy Distribution and offer useful insights for modeling and inference in settings involving heavy-tailed count data.
Keywords: Discrete Cauchy distribution, Probability generating function, Asymptotic analysis.
Mathematics Subject Classification (2010): 60E05, 60E10, 60E07, 62E10.

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On Stress-Strength Reliability for a Discrete Pareto-like Distribution

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Abstract:
In this paper, we consider a two-parameter discrete Pareto-like distribution introduced by **??**. Basic properties of the model are reviewed, and its asymptotic tail behavior is examined, confirming the Pareto-like heavy-tailed structure. The stress-strength reliability parameter $R = P(X > Y)$ is derived when both stress and strength follow this discrete distribution. An explicit expression for the reliability measure is obtained in the general case, and a closed-form representation is derived for the identically distributed case. Numerical illustrations are presented to demonstrate the effect of the model parameters on the reliability measure.
Keywords: discrete Pareto-like distribution, heavy-tailed distribution, Hurwitz zeta function, stress-strength reliability.
Mathematics Subject Classification (2010): 62E10, 60G70, 60E05.

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Entropy in Inflated Count Data: A Comparative Analysis

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Abstract:

Entropy is a fundamental measure of uncertainty in random variables and depends on the underlying probability distribution. Consequently, even small changes in the probability mass assigned to observed values may substantially affect the entropy. In this paper, we study the entropy of count data under an inflated distribution and present a theorem comparing the entropy of the inflated model with that of the corresponding regular distribution.

Keywords: Count data, Inflated distribution, entropy.

Mathematics Subject Classification (2010): 94A17, 60E05.

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Analysis of Persian Legal Document Networks Using Complex Network Techniques and Natural Language Processing

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Abstract:
Many real-world systems can be effectively modeled and analyzed using graph-based approaches. Despite the growing interest in legal network analysis, studies on Persian legal networks remain limited, particularly those integrating complex network science and artificial intelligence. This study investigates a large-scale Persian legal network constructed from 4,921 judicial rulings, 15 charge titles, and 807 legal documents from the criminal courts of the Islamic Republic of Iran. While the original dataset contained only judicial rulings, charge titles and legal documents were automatically extracted from ruling texts using natural language processing and an AI-based question-answering model. The extracted entities were used to construct and analyze bipartite and tripartite legal networks. Results show that the network exhibits several structural properties commonly observed in real-world complex networks. Furthermore, the proposed multi-level representation reveals meaningful relationships among judicial rulings, charge titles, and legal documents, providing valuable insights for legal network analysis.
Keywords: Complex networks, multipartite graphs, legal networks, natural language processing, intelligent question and answer.
Mathematics Subject Classification (2010): 99X99, 99X99, 99X99.

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Introducing EEGLAB-FDA: An EEGLAB Extension for Functional Data Analysis of EEG Signals

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Abstract:
Electroencephalography (EEG) generates rich time-resolved measurements of neural activity; however, conventional analytical approaches, including averaged event-related potentials (ERPs), may fail to adequately capture temporal complexity and variability across trials. Functional Data Analysis (FDA) provides an alternative statistical framework in which EEG recordings are represented as continuous smooth functions rather than isolated discrete observations. This approach enables investigation of entire temporal profiles, identification of meaningful functional patterns, and assessment of relationships among channels, conditions, and participants. To facilitate the application of FDA techniques in EEG research, we developed EEGLAB-FDA, a freely available plug-in designed for the MATLAB-based EEGLAB platform. The toolbox incorporates a broad collection of FDA procedures, including smoothing through B-spline and Fourier basis systems, functional principal component analysis (FPCA) with rotational options, derivative estimation, descriptive functional summaries, functional canonical correlation analysis, function-on-function regression with bootstrap-based inference, and spectral-domain FPCA implemented via the PACE methodology. EEGLAB-FDA offers an integrated workflow spanning preprocessing, statistical analysis, visualization, and export of results through a user-friendly graphical interface. The toolbox is intended to make advanced FDA methods accessible to investigators without extensive training in functional statistics. Its capabilities are illustrated using preprocessed auditory oddball EEG recordings. By combining methodological flexibility with practical usability, EEGLAB-FDA supports reproducible, interpretable, and scalable analysis of complex EEG datasets. The software, documentation, and tutorials are publicly accessible through GitHub and the EEGLAB extension repository.
Keywords: EEGLAB, Functional Data Analysis, MATLAB, EEG, GUI.
Mathematics Subject Classification (2010): 99X99, 99X99, 99X99.

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Bayesian Parameter and Reliability Estimation for a Bivariate Weibull Distribution: Parallel System

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Abstract:
This study develops a reliability modeling framework for multi-component systems using a Bivariate Weibull distribution under both independence and dependence assumptions. Dependence is introduced through the Gumbel copula, and parameters are estimated via maximum likelihood and Bayesian methods. Simulations show that independence-based models perform well only when components are truly independent, whereas ignoring dependence leads to biased reliability estimates. The copula-based model more accurately captures dependence, and Bayesian inference provides estimates comparable to maximum likelihood while offering credible intervals for parameters and system reliability.
Keywords: Bivariate Weibull, Bayes estimation, Parallel system reliability, Copula models, MCMC
Mathematics Subject Classification (2025): 62F15, 62N05, 62P30, 93B30.

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Bayesian Inference and Tracking of System Reliability

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Abstract:

This paper develops an extended Bayesian framework for estimating and tracking system reliability with a clear focus on sequential use of data and prior information. Within this framework, we establish new theoretical results, including the uniqueness of Beta priors under moment matching, bounds for series–parallel system reliability, asymptotic normality of posterior distributions, and Bayesian consistency. We further derive limit theorems for posterior mean convergence rates and credible-interval bounds for mixed systems. Numerical examples and sequential updating schemes demonstrate how the proposed framework can be applied in practice. Overall, the approach provides a rigorous, computationally light, and reproducible methodology for reliability analysis.

Keywords: Bayesian Inference, System Reliability, Posterior Consistency, Credible Bounds. **Mathematics Subject Classification (2020):** 62F15, 62N05, 62P30, 93B30.

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A Hierarchical Coding Framework for Master Data Identification in Large Enterprises

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Abstract:

In large enterprises, the absence of a standardized mechanism for identifying master data across distributed information systems remains a fundamental barrier to effective data governance. Organizations face challenges including fragmented data sources, inconsistent coding schemes, and the lack of a single source of truth. To address these challenges, we propose a hierarchical coding framework for master data identification, employing a four-level tree structure with shared and domain-specific nodes. The framework is validated through a case study in Iran's higher education system, involving multiple independently developed information systems and a comprehensive set of base entities across the domain. Results indicate that the framework establishes a unified identification system, enabling consistent coding, improved data integration, and enhanced governance capabilities. The study offers a practical, replicable solution for master data identification in large enterprises.

Keywords: Data Governance, Master Data Identification, Hierarchical Coding, Large Enterprises, Master Data Management.

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Optimal plan under Type-II Censoring Schemes in Multi-component Stress-Strength Reliability based on its Estimate and Cost

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Abstract:
In this paper, we consider a cut point M^* for number of failure times in the stress component of a multi-component stress-strength system based on Type-II censoring assumed as a truncated geometry distribution while the number of failure times in strength component is assumed fixed. The optimal schemes and the cut points can be considered and the most important is determination them so that the total cost of the test and the estimation of multi-component stress-strength reliability have been reached to minimum and maximum, respectively. A simulation study is carried out to check which different censoring schemes and cut points have the best performance in terms of the total cost and the estimation of multi-component stress-strength reliability. At the end, a real example is given to illustrate the proposed method.
Keywords: Multi-component stress-strength reliability, Type-II right censoring, Truncated geometry distribution.
Mathematics Subject Classification (2010): 62N01, 62N05.

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Evaluation of the performance of U-Net architecture in different batch sizes for segmenting the liver as an organ at risk in CT scans of Imam Reza Hospital

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Abstract:
Manual segmentation of the liver in CT images is time-consuming, operator-dependent, and prone to variability. In this study, we evaluate the performance of the U-Net architecture for segmenting the liver as an organ at risk in CT scans under different batch sizes. The model was trained on a clinical CT dataset from Imam Reza Hospital, and its performance was assessed using statistical segmentation metrics, including Dice coefficient, IoU, and average Hausdorff distance. Our analysis quantifies how batch size influences segmentation accuracy and boundary agreement, providing statistically grounded insights for optimizing U-Net training in medical image segmentation.
Keywords: CT Imaging, Deep Learning, Liver Segmentation, Radiotherapy, U-Net Architecture.

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A Bayesian Piecewise Exponential Cure Rate Model with Threshold Effects for Right-Censored Data

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Abstract:
In survival analysis, mixture cure models are highly effective for analyzing time-to-event data with a fraction of long-term survivors. This paper introduces a novel extension of the Cox proportional hazards mixture cure model by incorporating a smooth change-point threshold. We approximate the change-point using a sigmoid logistic function with a bandwidth parameter, enabling robust parameter estimation within a Bayesian framework. Extensive simulation studies confirm the accuracy of the proposed model, demonstrating small empirical standard errors and optimal 95% coverage probabilities for sample sizes up to $N = 500$. Furthermore, the practical utility of the model is illustrated using a breast cancer dataset from Omid Hospital, Mashhad. Our findings identify a significant age threshold of 41 years, revealing a 78% reduction in the hazard rate for older patients, and evaluate the effects of covariates such as tumor stage and hormone receptors using Highest Posterior Density (HPD) intervals.

Keywords: Threshold effect, mixture cure model, Bayesian inference, piecewise exponential model, Stan, Right-censored data
Mathematics Subject Classification (2010): 62N02, 62F15, 62P10.

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Explainable Ensemble Learning for Software Defect Prediction Using Fuzzy Integral-Based Aggregation

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Abstract:
The adoption of artificial intelligence in software defect prediction (SDP) has significantly improved predictive performance; however, the lack of transparency in complex models limits their practical applicability in critical software engineering environments. This paper proposes an explainable ensemble learning framework that integrates multiple base classifiers using a fuzzy integral-based aggregation mechanism. By modelling the interaction among classifiers through fuzzy measures, the approach captures both individual and collective predictive contributions. Additionally, interpretability is achieved by deriving importance indices that quantify the influence of features and models on final decisions. Experiments conducted on five NASA benchmark datasets (CM1, JM1, KC1, KC2, PC1) demonstrate that the proposed method achieves superior performance in terms of AUC, F-measure, and Matthews Correlation Coefficient (MCC) while providing meaningful explanations for prediction outcomes. The results highlight the potential of fuzzy-integral-based explainable AI in enhancing trust and reliability in SDP.
Keywords: Software Defect Prediction; Explainable AI; Fuzzy Integral; Ensemble Learning; Choquet Integral.
Mathematics Subject Classification (2010): 99X99, 99X99, 99X99.

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Deep Learning Helping to Realize Masnavi-e Maanavi

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Abstract:
This study introduces a novel quantitative methodology, borrowed from deep learning, to validate the hypothesis that Neynameh serves as a condensed summary of Masnavi-e Maanavi. We employ a multi-layered analytical framework combining ParsBERT fine-tuned on classical Persian texts with semantic embeddings, distribution analysis, spiritual journey kapping, and thematic analysis. Based on 18 verses of Neynameh and 26000 verses from Masnavi-e Maanavi, our analysis revealed a mean similarity score of 0.774 with relatively uniform distribution. The composite structural analysis yielded a score of 0.785, significantly above the validation threshold of 0.75. This methodology offers a replicable framework applicable to other texts in Persian literary tradition.
Keywords: Deep learning, Multi-layered, Masnavi-e Maanavi, ParsBERT, Similarity score.
Mathematics Subject Classification (2010): 62P99, 62P25.

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Dispersion measures based on varextropy for doubly truncated random variables

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Abstract:

Recently, considerable attention has been directed toward studying the variability of inaccuracy measures in information theory. In particular, **?** investigated the dispersion of information around the inaccuracy measure for doubly truncated random variables and demonstrated its significance. Motivated by this line of research, the present article introduces an inaccuracy measure for doubly truncated random variables based on varextropy and examines several of its fundamental properties.

Keywords: Doubly truncated random variable, Interval inaccuracy , Interval varjinaccuracy.

Mathematics Subject Classification (2010): 94A17, 62N05.

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From PCA to Autoencoders: A Unified Statistical Learning Perspective

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Abstract:
Learning meaningful representations of high-dimensional data is a foundational challenge in modern statistical learning. While classical linear methods like Principal Component Analysis (PCA) provide computationally efficient and interpretable solutions, deep nonlinear architectures such as Autoencoders (AEs) and Variational Autoencoders (VAEs) offer greater modeling flexibility. This paper presents a unified statistical learning perspective on these three paradigms, interpreting them as successive generalizations within a common empirical risk minimization framework with varying structural constraints and latent regularizations. To evaluate the practical utility of their learned representations, we investigate a two-stage pipeline where low-dimensional latent features are first learned in an unsupervised manner and subsequently fixed for downstream supervised learning tasks. Through extensive empirical evaluation on the MNIST dataset across various latent dimensions and distinct classification heads, we analyze the trade-offs between reconstruction, latent regularization, and predictive performance. Our results demonstrate that while nonlinear models (AE and VAE) significantly outperform PCA in low-dimensional regimes, the deterministic AE consistently yields superior downstream classification accuracy compared to VAE, highlighting the impact of probabilistic latent regularization on feature discriminability.

Keywords: Principal Component Analysis, Autoencoder, Variational Autoencoder, Representation Learning, Dimensionality Reduction.
Mathematics Subject Classification (2010): 62H25, 62H30, 62M45, 68T07.

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Control Charts for the Laplace Distribution: A Comparative Study Using Moments, L-Moments, Quantiles, and Bootstrap Methods

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Abstract:
The Laplace (double exponential) distribution is a symmetric distribution with heavier tails and a sharper peak than the normal distribution, making it suitable for modeling financial returns, signal processing, and other phenomena with excess kurtosis. Traditional control charts based on normality assumptions are inefficient for Laplace-distributed processes. This paper develops and compares control charts for the Laplace distribution using four different methodologies: classical moments, L-moments, quantile-based approaches, and bootstrap methods. We derive the theoretical control limits for each method, evaluate their performance through Monte Carlo simulations, and provide recommendations for practitioners. Results show that quantile-based and L-moment charts are more robust and effective than classical moment-based charts when the underlying distribution is Laplace.

Keywords: Laplace (Double Exponential) Distribution, L-moments, Quantiles, and Control Charts
Mathematics Subject Classification (2010): 60E05, 62G30, 62F40.

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Estimating the Stress-Strength Parameter Using a Dirichlet Process Mixture Model with Burr XII Kernels

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Abstract:

In this article, a new model is presented for modeling the distribution of stress and strength variables in a system. In this model, it is assumed that the distributions of the stress and strength variables are independent of one another, and a mixture of Dirichlet processes with Burr XII kernels is used to model the distribution of each of these variables. Prior distributions are selected for the parameters present in these models. The posterior distributions of the parameters have a complex form; therefore, Gibbs sampling is employed to generate samples from these distributions. The DirichletProcess package in R software is used to implement Gibbs algorithms in the mentioned mixture models. Under this new model, the stress-strength parameter is estimated. To evaluate the performance of the proposed model, a real dataset is utilized. The results obtained demonstrate satisfactory performance of the proposed model.

Keywords: Burr XII, Dirichlet process, Gibbs algorithm, Mixture model, Stress-Strength. **Mathematics Subject Classification (2010):** 62F15, 62G05.

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Ordered Ranked Set Sampling for Progressive-Stress Accelerated Life Tests under Type-II Censoring

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Abstract:
This paper investigates the performance of the ordered ranked set sampling scheme under progressive-stress accelerated life tests with type-II censoring. The lifetime of the item under use stress is assumed to follow a Weibull distribution, while the scale parameter is related to the applied stress through the inverse power law. Maximum likelihood estimators of the model parameters are derived under both ORSS and simple random sampling schemes. The finite-sample behavior of the proposed estimators is examined through simulation studies and numerical results. The findings indicate that ORSS yields more efficient estimation than SRS in terms of smaller absolute biases and mean squared errors.
Keywords: Maximum Likelihood Estimation, Ordered Ranked Set Sampling, Progressive-Stress Accelerated Life Test, Type-II Censoring.
Mathematics Subject Classification (2010): 99X99, 99X99, 99X99.

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Multi-Factor Multivariate Balakrishnan Skew-Normal Distributions

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Abstract:

The multivariate skew-normal distribution is beneficial for modeling departures from normality in data through parameters controlling skewness. In this paper, we consider the multivariate cases of the Balakrishnan skew-normal distribution introduced by Balakrishnan. We call these distributions multi-factor (two and three-factor) multivariate generalized Balakrishnan skew-normal distributions and denote by (SGBN). We present some useful theorems for introducing these distributions and give some theorems for producing them. Also, we investigate various properties of the mentioned distributions, including the moment generating functions, quadratic forms and linear transforms. Moreover, we derived the marginal distributions of the (SGBN) random vectors and we prove that any linear combination of three or two Azzalini's multivariate skew-normal random vectors is distributed as (SGBN). Finally, we obtain these distributions by conditioning as one of several stochastic methods which can be derived distributions.

Keywords: Multivariate Balakrishnan Skew-Normal Distribution, Orthant Probabilities, Moment Generating Function, Quadratic Forms, Marginal Distributions, Linear Transform.

Mathematics Subject Classification (2010): 62E15, 62H10, 60E05.

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Mixture modeling of normal mean-variance Birnbaum-Saunders factor analyzers under a Bayesian framework

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Abstract:
The mixture of factor analyzers (MFA) model, by representing component covariance matrices through a factor-analytic structure, efficiently reduces the number of free parameters and is widely used to uncover latent groups in high-dimensional data. While extensions to handle skewed data and asymmetry within latent groups have been explored in frequentest frameworks, they often face computational limitations. Here, we propose a Bayesian approach for normal mean-variance Birnbaum-Saunders MFA models, demonstrating its flexibility and performance on real dataset and highlighting computational advantages.
Keywords: Bayesian analysis, Mixture of factor analysis model, Normal mean-variance Birnbaum-Saunders distribution, and Seeds data.
Mathematics Subject Classification (2010): 99X99, 99X99, 99X99.

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Stress-strength reliability analysis under partially accelerated life testing using the inverse Weibull distribution

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Abstract:
The stress-strength reliability of a system is defined as the probability that its strength exceeds the applied stress, namely $R = P(X > Y)$. In this paper, we study the estimation of R when the strength X and stress Y are independent random variables following inverse Weibull distributions, and the strength variable is subjected to a step-stress partially accelerated life test. The inverse Weibull model provides a flexible alternative to lifetime distributions with restrictive failure-rate behavior. Since the maximum likelihood estimator of R and its asymptotic distribution cannot be obtained in closed form, numerical estimation and asymptotic confidence intervals are considered. A real dataset is analyzed to illustrate the applicability and performance of the proposed model.

Keywords: Partial acceleration, Inverse Weibull distributions, ML method, and Reliability analysis.
Mathematics Subject Classification (2010): 99X99, 99X99, 99X99.

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Performance of the auto.arima() Function in Recovering True ARIMA Models Order Under Three Different Stationarity Tests

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Abstract:
The auto. arima () function in R is widely used for automated ARIMA model selection in time series analysis. However, its performance may depending on the choice of stationarity test for determining the order (p, d, q). This study investigates how the auto. arima () function behaves under three unit root tests (three stationarity tests); Augmented Dickey-Fuller (ADF), Kwiatkowski–Phillips–Schmidt–Shin (KPSS), and Phillips–Perron (PP), when determining the correct ARIMA model order (p, d, q). Using 38 simulated ARIMA (p, d, q) models with varying parameters, we compute the percentage of correct identification of (p, d, q) simultaneously for each test. Among the three unit root tests, auto. arima () function on KPSS achieves the highest mean correct identification rate (20–21%), followed by ADF and PP (16–18%); however, all yield 0% accuracy for any model containing a unit root (d ¿ 0).
Keywords: ARIMA model,auto.arima(),ADF test,KPSS test,PP test,time series,stationarity
Mathematics Subject Classification (2010): 62M10, 62F03.

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A Novel Approach for Statistical Shape Analysis Using the Square Root Velocity Function Representation

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Abstract:
Statistical shape analysis for manifold-valued data poses significant challenges in comparing shapes and modeling their variability. Classical methods based on tangent space principal component analysis (TPCA) rely on local linearization and often suffer from limitations in stability and interpretability. In this work, we introduce a novel framework for functional principal component analysis (FPCA) in the Sobolev space $H^1([0,1])$, which naturally incorporates geometric information of curves. Shapes are represented using the square root velocity function (SRVF) and aligned via the Karcher mean to remove phase variability. The variability is then analyzed globally in H^1, where the covariance operator accounts for both the functions and their derivatives. We clarify the distinct advantages of this global approach over local TPCA approximations and standard L^2-based FPCA. We show theoretically that the resulting principal components are equivalent, up to first-order variability, to those obtained from tangent-space approaches. Experiments on real two-dimensional contour datasets demonstrate that the proposed method captures most of the structural variability with few components while maintaining high numerical stability and reconstruction accuracy.
Keywords: Statistical Shape Analysis,Square Root Velocity Function,Functional Principal Component Analysis,Banach Space,Covariance Operator
Mathematics Subject Classification (2010): 62R30, 62H25.

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Beyond Ancillarity: A Unified Theory of $\mathscr{H}$-Sufficient Statistics for Optimal Unbiased Estimation

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Abstract:

Nayak and Sinha (2012) established that the uncorrelatedness of any UMVUE with all unbiased estimators of zero implies certain conclusions of the Rao–Blackwell and Lehmann–Scheffé theorems, and that the conditional mean and variance of a UMVUE are independent of any ancillary statistic. In this paper, we employ the concept of $\mathscr{H}$-sufficient statistics introduced by Homei (2019a) to generalize and strengthen these results in three directions.
(i) We prove that if $H(X)$ is a complete $\mathscr{H}$-sufficient statistic for $a(\theta)$, then the Lehmann–Scheffé condition (1.1) holds if and only if $g(X)$ is a function of $H(X)$ (Theorem 3.1), thereby extending Theorem 2.1 of Nayak and Sinha (2012) from complete sufficient statistics to the broader class of complete $\mathscr{H}$-sufficient statistics.
(ii) We show that if $g(X)$ is UMVUE and $V(X)$ is ancillary, then $E[g(X) \mid V] = a(\theta)$ almost surely; if $V(X)$ is merely first-order ancillary, then $\mathrm{Cov}(g(X), V) = 0$ (Theorem 3.2), which strengthens Theorem 2.2 of Nayak and Sinha (2012).
(iii) We establish a necessary condition $E[V \mid g(X)] = 0$ for every first-order ancillary V with $E(V) = 0$ (Theorem 3.3), generalizing Theorem 2.3 of Nayak and Sinha (2012).
We further provide an interpretation of Basu's theorem in the context of $\mathscr{H}$-sufficiency (Section 4) and illustrate all results with fully worked examples, including the $U(\theta, \theta + 1)$ location family whose minimal sufficient statistic is incomplete. Our unified framework extends classical UMVUE theory and remains applicable even when completeness of the minimal sufficient statistic fails.

Keywords:
Rao–Blackwell theorem, Lehmann–Scheffé theorem, Uniformly minimum-variance unbiased estimator, Incomplete minimal sufficient statistic, $\mathscr{H}$-sufficient statistic, Ancillary statistic.

Mathematics Subject Classification (2010): $62F10$, $62B05$, $62F99$.

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Generalized $\mathscr{H}$-Sufficient Statistics and the Construction of UMVUEs: New Perspectives and Extensions

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Abstract:
This paper introduces the concept of an $\mathscr{H}$-sufficient statistic and explores its theoretical implications in the derivation of uniformly minimum variance unbiased estimators (UMVUEs). By leveraging this framework, we extend classical results associated with the Rao-Blackwell and Lehmann-Scheffé theorems, particularly in settings where a complete sufficient statistic is unavailable. The proposed approach not only clarifies several longstanding examples in statistical literature but also yields novel interpretations of optimality conditions. Furthermore, we establish connections between $\mathscr{H}$-sufficiency and Basu's theorem, demonstrating how independence and uncorrelatedness criteria can be systematically utilized to identify optimal estimators. The results provide a unified and flexible methodology for handling incomplete minimal sufficient statistics in parametric inference.
Keywords: Rao-Blackwell theorem, Lehmann-Scheffé theorem, $\mathscr{H}$-sufficient statistic, incomplete sufficient statistics, Basu's theorem, UMVUE.
Mathematics Subject Classification (2010): 62F10, 62B05, 62F99.

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Bayesian Joint Modelling of eGFR Trends on Survival Risk among Undergoing Deceased Donor Renal Transplantations

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Abstract:
Objectives: Among renal transplant recipients, a progressive decrease in estimated glomerular filtration rate (e GFR) biomarker frequently occurs after graft failure. This study aimed to determine the simultaneous longitudinal effect of e GFR and renal function, and other risk factors on survival risk after renal transplantation. Materials and Methods: This retrospective cohort study includes 484 Iranian patients with end-stage renal disease (ESRD) who received a cadaveric renal transplant between 2015 and 2020. Data extracted from the registry of Montaseriyeh Transplant Center, Mashhad, Iran. Joint modelling for longitudinal e GFR measurements and time to death was used to identify the specific role of biomarker and risk factors on patient's survival risk. All analyses were performed using spss (V. 25) and the JMbayes2 package, jm function in RStudio-2026.04.0-526. Results: The mean age of recipients was 38.57 ± 11.3 years. Baseline log-e GFR was the strongest predictor of subsequent trajectory (P ¡ 0.001). Donor age was significantly and negatively associated with the longitudinal outcome (= -0.0027, [%95 Cr I: -0.0040 to -0.0015], P¡ 0.001). Married patients had a markedly higher hazard (exp (1.015) 2.76). Age and BUN showed positive but non-significant associations. The value of log-e GFR was associated with a change in the instantaneous hazard of exp (-0.006), i. e., an approximate %0.4 reduction in hazard, although this relationship was not statistically significant (= -0.0060 [95\{}% Cr I: -0.017 to 0.003]; posterior P = 0.248).
Keywords: Joint modelling,Longitudinal eGFR,Estimated glomerular filtration rate,Renal transplantation
Mathematics Subject Classification (2010): 62 − XX.

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Estimation of the Mean Residual Life Function Using Neoteric Ranked Set Sampling

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Abstract:
The mean residual life (MRL) function is one of the fundamental concepts in survival analysis. The MRL is easily interpretable and particularly useful for conveying the survival information to patients. Ranked set sampling (RSS) is a sampling design useful for situations where precise quantification of units is costly or difficult, but ranking them based on associated variables is easy with negligible cost. In recent years, different modifications of RSS have been introduced to enhance its efficiency. This paper investigates the estimation of the MRL function using Neoteric Ranked Set Sampling (NRSS), a notable modification of RSS. We compare the proposed estimator with its counterparts in RSS and SRS using Monte Carlo simulation. Our results show that the proposed estimator is more efficient than its counterparts for small and moderate sample sizes.
Keywords: Mean residual life, Neoteric ranked set sampling, Monte Carlo simulation, Ranked set sampling.
Mathematics Subject Classification (2010): 62D05, 62G05.

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Temporal Changes Social Interactions Among Older Adults: A Cross-Lagged Panel Modeling Approach with PLSe2 Estimator

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Abstract:

Social interactions in later life play a critical role in shaping psychological and social well-being. This study examined the longitudinal dynamics between positive and negative social exchanges among older adults using a cross-lagged panel model estimated with the PLSe2 approach. PLSe2 provides efficient and consistent parameter estimates with robust performance under normal and non-normal data distributions, while improving the accuracy of standard errors and overall model evaluation in complex latent variable structures. The data were based on simulated observations from the Later Life Study of Social Exchanges including 916 adults aged 65 years and older with six-month measurement intervals. Results showed significant positive autoregressive effects, indicating stability of both constructs over time. Significant negative cross-lagged effects were also found, suggesting that negative exchanges reduce later positive interactions and vice versa. Managing negative social exchanges and strengthening positive interactions may contribute to improved psychosocial well-being and sustained social functioning in older adults over time.

Keywords: Social Interactions, Cross-Lagged Panel Model, PLSe2 Estimator.

Mathematics Subject Classification (2010): $62P10$.

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A Comparative Performance Analysis of Structural Equation Modeling Approaches: A Monte Carlo Simulation Study

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Abstract:
This Monte Carlo simulation study compared the performance of three structural equation modeling approaches CB-SEM, PLS-SEM, and GSCA within a mediation model under varying sample sizes, data distributions, and indicator counts. Using full factorial design with 500 replications per scenario, results revealed that CB-SEM provided the most accurate estimates under normality and larger samples ($N \geq 250$), yet suffered convergence issues in small or severely non-normal conditions. PLS-SEM demonstrated superior convergence rates and statistical power across all scenarios, albeit with systematic attenuation bias. GSCA offered balanced intermediate performance, particularly robust under distributional violations. Increasing indicators per construct benefited CB-SEM most substantially. No single method proved universally superior; rather, selection should align with research objectives, sample availability, and data characteristics. These evidence-based findings offer practical guidance for biostatisticians and health researchers in choosing appropriate SEM methodologies.
Keywords: CB-SEM, PLS-SEM, GSCA, Monte Carlo Simulation,Mediation Analysis.
Mathematics Subject Classification (2010): 62P10.

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Uncovering growth patterns in infants: a latent class growth modeling approach

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Abstract:
Understanding heterogeneity in infant growth is essential for early identification of atypical development. This study applied latent class growth modeling to anthropometric data from 173,204 infants under two years of age in Razavi Khorasan Province, Iran. Weight and height measurements were extracted from electronic health records at five time points (birth, 6, 12, 18, and 24 months). Model selection, guided by the Bayesian Information Criterion, bootstrap likelihood ratio test, entropy, and clinical interpretability, revealed three distinct growth trajectories: normal growth (65.23%), rapid growth (21.91%), and slow growth (12.88%). Sex-specific differences were evident across all classes and time points. The identification of a substantial subgroup exhibiting rapid weight gain highlights an opportunity for targeted obesity prevention, while the detection of a slow-growing group supports earlier nutritional intervention. Latent class growth modeling provides a robust framework for population-level growth monitoring and enables data-driven strategies to promote optimal child health and development.
Keywords: Anthropometry,growth trajectories,latent class growth modeling,infant,Iran
Mathematics Subject Classification (2010): 62P10.

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Boosting K-Nearest Neighbor Regression Performance for Longitudinal Data through a Novel Learning Approach

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Abstract:
Longitudinal studies often require flexible methodologies for predicting response trajectories based on time-dependent and time-independent covariates. This study proposes a novel extension of K-Nearest Neighbor regression, Clustering-based KNN Regression for Longitudinal Data (CKNNRLD). In CKNNRLD, data are first clustered using the KML algorithm, and the nearest neighbors are then searched within the relevant cluster rather than across the entire dataset. The method was evaluated through simulation studies and applied to a real longitudinal spirometry dataset. Compared with standard KNN, CKNNRLD improved prediction accuracy and computational efficiency for longitudinal responses.
Keywords: Longitudinal studies, K-nearest neighbors, K-means clustering, machine learning, processing speed
Mathematics Subject Classification (2010): 62G08, 62H30, 62M10.

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Determining the Optimal Number of Events Per Variable (EPV) in Rare Event Competing Risk Models: Simulation study

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Abstract:

Background: In survival analysis with competing risks, especially in the presence of rare events, accurate estimation of the cumulative incidence function and reliable variable selection remain challenging. Penalized methods have been widely used for variable selection; however, their performance depends on factors such as events per variable (EPV), censoring rate, and correlation among predictors. This study aimed to evaluate the impact of EPV and data complexity on model performance and to assess the adequacy of the conventional EPV=10 rule under rare event settings. Methods: A simulation study was conducted using 72 scenarios defined by combinations of EPV levels (2.5, 5, 10, and 15), correlation (0.2 and 0.9), censoring rates (30%, 50%, and 70%), and sample sizes (300, 500, and 700). Each scenario was replicated 1,000 times. The first tuning parameter of penalized methods was pre-optimized and fixed to isolate the effects of EPV and other factors. Model performance was evaluated based on bias and mean squared error (MSE) in estimating the cumulative incidence function. Results: Increasing EPV led to a substantial reduction in bias and MSE, with more pronounced improvements at lower EPV levels (up to approximately 10), followed by a plateau at higher levels (10–15). High correlation and heavy censoring adversely affected performance, slowing the rate of improvement and resulting in considerable residual error even at EPV=10. Larger sample sizes improved overall stability and partially mitigated these effects; however, under severe censoring and high correlation, EPV=10 remained insufficient. The performance of different variable selection methods was largely comparable across scenarios. Conclusion: The findings suggest that the conventional EPV=10 rule may not be adequate in competing risks settings with rare events, particularly in the presence of high censoring and strong correlation. A higher and context-dependent EPV is recommended to achieve more accurate and stable estimates.

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Shrinkage Bayes Estimation for Matrix-Variate Normal Mean Matrix under Balanced Loss Function

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Abstract:
We study Bayesian estimation of the mean matrix in a matrix-variate normal distribution with known covariances and a conjugate prior. Under a balanced matrix composite loss function, we derive the Bayes estimator as a convex combination of the posterior mean and the observed data, controlled by a shrinkage parameter $\omega \in [0, 1]$. The posterior mean formula $\Theta_n = \frac{1}{2}(\Theta_0 + X)$ is established. A simulation study using non-diagonal AR(1) covariances confirms the theoretical findings, showing that the optimal ω lies strictly between zero and one under high noise, with the optimal estimator achieving 38.4% MSE reduction over the posterior mean. Performance is evaluated using MSE, PSNR, and SSIM metrics.

Keywords: Balanced loss function, Bayes estimator, Image denoising, Matrix-variate normal distribution, Shrinkage estimation.
Mathematics Subject Classification (2010): $62J07, 62F15$.

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From Variables to Relationships: The Role of Networks and Knowledge Graphs in Data Analytics

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Abstract: Statistical methods have long provided the foundation for extracting knowledge from data. While traditional analyses primarily focus on variables and attributes associated with individual entities, many contemporary datasets also contain valuable information embedded in relationships, interactions, and dependencies among entities. The increasing availability of relational data has stimulated the development of network-based analytical frameworks that extend and enrich classical statistical perspectives. Community detection, link prediction, and multilayer network analysis provide powerful tools for exploring structural patterns and interaction dynamics in complex systems. Knowledge graphs further enhance relational representations by incorporating semantic information, enabling richer knowledge discovery and reasoning. Integrating attribute-based and relationship-centric perspectives offers a broader framework for understanding interconnected data and highlights the growing role of networks and knowledge graphs in the evolving landscape of data analytics.

Keywords: Network analysis, knowledge graphs, community detection, link prediction, multilayer networks.
Mathematics Subject Classification (2010): 05C82, 68R10, 68T30.

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Pen_GMERF: A Penalized Generalized Mixed-Effects Random Forest for High-Dimensional Hierarchical Data

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Abstract:
High-dimensional hierarchical data are increasingly encountered in biomedical research, where clustered observations and repeated measurements complicate statistical analysis. Generalized linear mixed models (GLMMs) account for hierarchical structures but may be limited in high-dimensional settings, whereas random forests capture nonlinear relationships but ignore within-cluster dependence. To address these limitations, we propose Pen_GMERF, which integrates GLMMLASSO with the Generalized Mixed-Effects Random Forest (GMERF) to enable simultaneous variable selection and hierarchical modeling. This approach aims to improve prediction accuracy, stability, and interpretability for high-dimensional clustered data.

Keywords: Pen_GMERF (Penalized Generalized Mixed-Effects Random Forest), GMERF (Mixed-Effects Random Forest), high-dimensional, Hierarchical, PMAD (Mean Absolute Deviation), PMCR (Predictive Misclassification Rate).
Mathematics Subject Classification (2010): 99X99, 99X99, 99X99.

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Efficient Bayesian Inference for Stress-Strength Reliability in Gompertz Distribution via Ranked Set Sampling

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Abstract:
The Gompertz distribution, with its exponentially increasing hazard rate, is widely used in reliability engineering and survival analysis. However, estimating stress-strength reliability under this distribution has received limited attention. Conventional simple random sampling (SRS) is inefficient when precise measurements are costly or time-consuming. Ranked set sampling (RSS) addresses this limitation by using inexpensive ranking before measurement, extracting more information without increasing sample size. This study develops a Bayesian estimation of stress-strength reliability $R = P(X < Y)$ for the Gompertz distribution under RSS. Bayesian estimators are derived under a squared error loss function using the Metropolis-Hastings algorithm. The significance of this work is providing an efficient, low-cost, and high-precision method for reliability estimation when accurate measurement is expensive or difficult.
Keywords: Ranked Set Sampling, Gompertz Distribution, Stress-Strength Reliability, and Metropolics-Hastings Algorithm.
Mathematics Subject Classification (2020): 62Exx, 62F10, 62F15.

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Feature Ranking and Incremental Selection for High-Dimensional Classification

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Abstract:
High-dimensional datasets in genomics pose classification challenges due to the curse of dimensionality and redundant features. Feature selection addresses this by identifying informative subsets to improve model interpretability, efficiency, and performance. However, many existing feature selection methods lack stability, meaning that small changes in the data can lead to drastically different selected feature subsets. This paper introduces an integrated stability-ranked feature selection (ISRS) framework designed to address this limitation. ISRS combines ensemble-based feature ranking with a novel stability metric to identify a predictive feature subset. We evaluate ISRS on two real datasets, demonstrating its superior stability and competitive or improved classification accuracy compared to established regularized methods like Lasso and Elastic Net.

Keywords: High-dimensional classification,Feature selection,Support vector machine,Feature ranking,Selection stability
Mathematics Subject Classification (2010): 62J07, 62F07, 62H30.

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A Machine Learning-Driven Framework for the Implementation of Statistical Population Registers: A Hybrid Intelligent Approach

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Abstract:
The rapid evolution of data ecosystems has necessitated a paradigm shift in how national statistical organizations construct and maintain population registers. The traditional reliance on costly, periodic censuses is increasingly being replaced by the implementation of Statistical Population Registers (SPR) derived from multi-source administrative data. However, the operationalization of an SPR is not merely a data aggregation task; it is a complex engineering challenge requiring the reconciliation of heterogeneous datasets characterized by noise, missing identifiers, and structural variations. In the context of Persian administrative registries, these implementation challenges are particularly pronounced. The lack of standardized orthography and the absence of a unified, error-free identifier create significant barriers to effective record integration. Conventional deterministic methods often prove inadequate in handling such linguistic and structural complexities, while purely probabilistic linkage techniques frequently suffer from computational bottlenecks and suboptimal classification precision. This research addresses these challenges by proposing a robust, machine learning-driven framework for the implementation of an SPR. By introducing a hybrid intelligent approach that synergizes the structural rigor of Probabilistic Record Linkage (PRL) with the adaptive predictive power of supervised machine learning—specifically decision tree classifiers—this study provides a scalable solution for high-fidelity data integration. The central objective of this research is to establish an automated pipeline that minimizes human-in-the-loop requirements while maximizing linkage accuracy. This paper evaluates the proposed framework through rigorous empirical testing on simulated administrative datasets, demonstrating how the integration of machine learning leads to superior performance in the implementation of reliable, modern statistical registers.
Keywords: Intelligent System,Machine Learning,Administrative Data Integration,Record Linkage
Mathematics Subject Classification (2010): 99X99, 99X99, 99X99.

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The Asymmetric Laplace Process: A Powerful Alternative to AL in Spatial Quantile Regression

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Abstract:
Quantile regression is a powerful tool for modelling the conditional distribution of a response variable, particularly when interest lies in the tails of the distribution. Standard quantile regression models typically employ the asymmetric Laplace (AL) distribution under the assumption of independent errors, and therefore cannot capture spatial dependence when it exists in the data. To address this, Lum and Gelfand (2012) introduced the Asymmetric Laplace Process (ALP), which incorporates a latent Gaussian process to capture spatial correlation within the error structure. We conduct a simulation-based comparison evaluating the ALP against the standard AL model under varying levels of spatial correlation. Results show that the ALP achieves lower RMSE for the regression parameter in almost all scenarios. However, credible interval coverage for β_0 declines substantially as the spatial range increases, ultimately falling below the nominal level. This deterioration in coverage suggests a potential identifiability issue between the spatial process and the intercept under strong spatial correlation. We conclude that while ALP offers improved point estimation, its credible intervals should be interpreted with caution in the presence of strong spatial dependence.
Keywords: Spatial quantile regression, Asymmetric Laplace process, Bayesian inference, Stan.
Mathematics Subject Classification (2010): 62F15, 62M30, 62J05.

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Intelligent Anomaly Detection with Deep Reinforcement Learning for Industrial Inspection

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Abstract:

This work tackles pixel-level anomaly detection in industrial inspection with scarce defective data. We introduce a semi-supervised deep reinforcement learning framework enhancing detection via an adaptive neural batch sampler and robust autoencoder, balancing exploration and exploitation for subtle anomalies. MVTec AD evaluations show superior performance (AUC: 0.949 $\pm$ 0.03, $F1_{\max}$: 0.561 $\pm$ 0.20), showing favorable results compared to structurally comparable lightweight methods, and standard deviations confirm robustness despite the increased mean accuracy. This offers a scalable, statistically robust solution for manufacturing quality assurance.

Keywords: Anomaly Detection, Reinforcement Learning, Outlier Detection, Computer Vision, Semi-Supervised Learning, Adaptive Batch Sampling

Mathematics Subject Classification (2010): $68T07$, $68T45$, $62H30$.

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Evaluating Large Language Models on the Iranian University Entrance Exam: A Multi-Subject Persian Benchmark

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Abstract:
This paper presents a comprehensive benchmark of state-of-the-art Large Language Models (LLMs)—specifically Gemini v3, GPT-5.1, and DeepSeek 3.2—on the 2025 Iranian National Entrance Exam (Konkur). We evaluated the zero-shot performance of these models across three major academic streams: Mathematics, Experimental Sciences, and Humanities. The results reveal a significant "Specialization Gap." GPT-5.1 demonstrated superior logical reasoning capabilities, achieving the highest accuracy in Mathematics (50.0%). Conversely, Gemini v3 exhibited dominance in knowledge-intensive domains, securing top ranks in Experimental Sciences (79.5%) and achieving near-expert performance in Humanities (95.0%). Notably, GPT-5.1's performance in the Humanities stream dropped to 20.7%, highlighting a critical deficiency in processing localized cultural contexts. This study provides the first granular map of LLM capabilities across Persian academic disciplines.

Keywords: Large Language Models (LLMs), Persian Benchmark, Iranian National Entrance Exam (Konkur), GPT-5.1, Gemini v3, DeepSeek 3.2, Zero-shot Learning, Multimodal Evaluation.

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Optimal Designs for the Proportional Interference Models with Nonnegative Proportionality Constant and Correlated Observations

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Abstract:
In block experiments where a treatment applied to one plot affects neighboring plots, interference models are used to account for these neighbor effects. A special class is the proportional interference model, in which each neighbor effect is a proportion of the direct treatment effect.

We study the one-sided proportional interference model in which only the left neighbor contributes a positive proportion of the direct treatment effect, and observations follow a first-order circular autoregressive correlation structure. Under this model we derive exact optimal designs for correlated observations.

Keywords: Interference models, Circular block designs, Neighbor balanced designs, Universally optimal criterion.
Mathematics Subject Classification (2010): 62K05, 62K10.

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Multi-component Reliability Estimation in Kumaraswamy Inverse Weibull Distribution

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Abstract:
In this paper, the statistical inference on multi-component stress-strength parameter with non-identical-component strengths, based on Kumaraswamy inverse Weibull distribution under first failure progressive censoring samples, is considered. The problem is solved in two cases. First, when one parameter is unknown, the Bayes estimation and highest posterior density intervals are obtained. In this case, the MCMC method is used to obtain the Bayesian inference. Second, when all parameters are different and unknown, the Bayesian estimation are studied. The Monte Carlo simulation is employed to compare the estimations. Based on the simulation results, it is observed that the informative priors perform better than the non-informative ones.
Keywords: Progressive first failure censoring,Multi-component stress-strength parameter,MCMC method
Mathematics Subject Classification (2010): 62F15, 62N05.

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Stochastic Anchor Points in Multiobjective Optimization

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Abstract:

Proper efficiency is a foundational solution concept in deterministic multiobjective optimization. Recently, the notion of *anchor points* was introduced to classify properly efficient solutions that solve a weighted sum scalarization problem where at least one objective weight is zero. In practical applications, however, objectives are frequently corrupted by stochastic uncertainty. This paper generalizes the concept of anchor points to the framework of Stochastic Multiobjective Optimization (SMOP) using a probabilistic expected value approach. We introduce the concept of Stochastic Anchor Points and characterize them via properties of the stochastic objective space, the stochastic tangent cone, and the stochastic normal cone.

Keywords: Stochastic multiobjective optimization; Anchor points; Proper efficiency; Expected value scalarization; Normal cone; Uncertainty analysis.

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Graphical Finite-Population Sampling with Adaptive Monte Carlo Tree Search

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Abstract:
Graphical finite-population sampling represents prescribed first-order inclusion probabilities by bars, or unions of bar segments, on the unit interval. A horizontal uniform random line induces a sample, while the geometry of overlaps determines the second- and higher-order inclusion probabilities. Starting from the fixed-size graphical construction equivalent to Madow's systematic design, exchanges of interchangeable segments generate alternative fixed-size designs without changing the prescribed first-order probabilities. This paper combines that feasible design generator with an adaptive population-based Monte Carlo tree search. The implementation uses upper-confidence tree selection, quality-adaptive mutation scales, parallel two-scale rollouts, a safety cutoff, and restarts from the best design after stagnation. A tuning experiment based on the exact Narain–Horvitz–Thompson variance indicates that the restart and rollout mechanisms materially affect the quality of the best graphical design found.
Keywords: Finite-population sampling, graphical sampling, inclusion probabilities, Monte Carlo tree search, Narain–Horvitz–Thompson estimator.
Mathematics Subject Classification (2010): 62D05, 62K05, 90C59.

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A Tutorial on Classification Methods for Educational and Behavioral Research with R

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Abstract:
Classification is a core problem in statistical learning. Linear classification methods offer significant strengths, especially in educational and behavioral research. This tutorial introduces logistic regression (binary, multinomial, ordinal) and discriminant analysis methods. Linear classification methods are categorized into three groups: discriminant analysis, logistic regression, and hybrid approaches. Each method's mathematical foundations and implementation algorithms are explored, emphasizing their application in education and behavioral research. Logistic regression models are effective for handling binary, multi-class, and ordinal outcomes. Simulations in R illustrate their practical application across different contexts. Linear classification methods are valuable for their interpretability, statistical efficiency, and theoretical rigor. Future research will focus on regularization, computational efficiency, and integration with nonlinear approaches.

Keywords: Linear Classification, Logistic Regression, Discriminant Analysis, Statistical Learning.
Mathematics Subject Classification (2010): 62H30, 62J12, 62 − 07.

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Performance of Machine Learning Algorithms in Predicting 5-Year Breast Cancer Survival: A Systematic Review and Network Meta-Analysis

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Abstract:

Background: The accurate prediction of 5-year survival is critical for risk stratification and personalizing treatment plans in breast cancer. A proliferation of machine learning (ML) algorithms has been developed for this prognostic task, but their comparative performance remains unclear due to the absence of direct comparisons in the literature.
Methods: We conducted a systematic review and network meta-analysis (NMA) following PRISMA-NMA guidelines, searching PubMed, Web of Science, Scopus, and ScienceDirect from inception until July 24, 2023 for studies developing or validating ML models for 5-year breast cancer survival prediction. The primary outcome was sensitivity, with secondary outcomes of specificity and accuracy. A frequentist random-effects NMA was performed using R software (version 4.3.1) with the 'netmeta' package to synthesize evidence and rank algorithms. Study quality was assessed using a modified QUADAS-2 tool. Thirteen studies were included in the final analysis, evaluating nine ML algorithms.
Results: The NMA of included studies demonstrated a clear performance hierarchy among ML algorithms. Ensemble methods consistently outperformed other approaches, with Boosting algorithms achieving the highest rank for sensitivity (P-score: 81.3%) and Random Forest ranking highest for specificity (P-score: 83.4%). Neural Networks demonstrated the highest estimated accuracy (P-score: 74.6%). In contrast, traditional statistical methods underperformed, with Logistic Regression among the lowest-ranked algorithms for both sensitivity (6%) and accuracy (16.4%). The network was well-connected, and inconsistency tests supported the validity of the model for comparative analysis.
Conclusion: This NMA demonstrates that ensemble ML methods, specifically Boosting and Random Forest, achieve superior performance for predicting 5-year breast cancer survival. Boosting emerges as the optimal algorithm for maximizing sensitivity, while Random Forest excels in specificity, providing clinicians with evidence-based guidance for algorithm selection based on clinical priorities. These findings establish a crucial performance hierarchy to inform future model development and clinical implementation in precision oncology.
Keywords: Breast Neoplasms; Machine Learning; Network Meta-Analysis; Prognosis; Survival Analysis; Artificial Intelligence.

Variable Selection in Linear Regression: A Comprehensive Guide to Theory, Methods, and Applications

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Abstract:
Variable selection is a key step in building robust and interpretable linear regression models, particularly in high-dimensional settings. This tutorial reviews major variable selection strategies and provides practical guidance for selecting an appropriate method based on data structure and study goals. We summarize four classes of approaches: subset selection procedures (best subset, forward, backward, and stepwise), shrinkage/regularization methods (Ridge, Lasso, and Elastic Net), dimension-reduction approaches (Principal Component Regression and Partial Least Squares), and extensions for structured or multivariate outcomes (e.g., Group Lasso and multivariate shrinkage regression). We emphasize that no single method is optimal for all problems; the choice depends on interpretability, prediction performance, multicollinearity, and computational constraints. Modern implementations in SPSS, R, Stata, and Python support statistically sound and actionable modeling.

Keywords: Variable Selection, Linear Regression, Lasso, Ridge, Elastic Net, Principal Component Regression (PCR), Partial Least Squares (PLS), High-Dimensional Data

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New Insights into the Spectral Coherence of Simple Time Series

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Abstract:
Simple processes (SPs) are spectrally correlated processes characterized by a Loeve bi-frequency spectrum supported on a countable set of curves. This study introduces a definition of spectral coherence for discrete-time harmonizable simple processes (DTHSPs) and develops robust estimators for both known and unknown spectral structures. We employ periodogram covariances and establish asymptotic properties for the known case, while utilizing a spectral ciphering-based method for the unknown case. Additionally, we formulate multiple testing procedures to classify pairs of DTHSPs as coherent or incoherent. Theoretical results are validated via comprehensive simulations.
Keywords: Harmonizable Simple processes, Spectral Coherence, Periodogram, Spectrally Correlated Time Series, Coherence.
Mathematics Subject Classification (2010): Primary 62M15; secondary 62H20.

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Investigating the Relationship between Iranian Insurance Companies' Solvency Ratio and Insurance Policy Sales

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Abstract:
The Central Insurance of Iran introduced the financial solvency ratio as a supervisory tool for insurance companies following the approval of Regulation No. 69 in February 2012. This metric assesses an insurer's financial capacity to cover accepted risks and classifies companies into five levels, with Level 1 (ratio above 100%) considered desirable. Despite regulatory flexibility regarding remedial actions, market perception increasingly associates higher solvency ratios with insurer reliability. This paper examines whether the annual publication of solvency ratios influences insurance policy sales. Using data from 16 Iranian insurance companies spanning 2012-2024, we construct a "co-movement" index to measure the directional alignment between solvency ratio changes and subsequent year premium writings. Our methodology accounts for the inherent time lag in consumer response and addresses non-stationarity concerns in time series data. The findings provide preliminary evidence on the market discipline role of solvency disclosure in Iran's insurance industry.
Keywords: Solvency Ratio, Insurance Regulation, Market Discipline, and Policy
Mathematics Subject Classification (2010): 62P05, 91B30, 62H20.

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Bayesian Inference for VAR-GoGARCH Models under Gaussian and Skew-Normal Innovations

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Abstract:

Modeling multivariate financial time series requires flexible frameworks capable of capturing dynamic dependence, conditional heteroscedasticity, and asymmetric innovation distributions. This paper develops a Bayesian estimation framework for VAR-GoGARCH models under both Gaussian and skew-normal innovations. Posterior inference is performed using a Metropolis–Hastings Markov chain Monte Carlo (MCMC) algorithm, while the mixing matrix is estimated separately via the νSOBI decomposition. The proposed methodology is evaluated through Monte Carlo experiments under correctly specified and asymmetric innovation settings. The results show that the Bayesian estimator consistently achieves lower root mean squared errors than the classical maximum likelihood estimator. Moreover, when the innovation distribution is correctly specified as skew-normal, the proposed approach substantially improves volatility estimation, reducing the mean squared error by approximately 59% relative to the Gaussian maximum likelihood benchmark. Overall, the findings highlight the importance of combining Bayesian inference with flexible innovation distributions in multivariate volatility modeling.

Keywords: Bayesian inference, VAR-GoGARCH model, Skew-normal distribution, Markov chain Monte Carlo, Volatility estimation.
Mathematics Subject Classification (2010): 62F15, 62M10, 62H12, 91G70.

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The Bayesian nonparametric Estimation of entropy and extropy based on right censored data

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Abstract:
Entropy and extropy are central measures in information theory. In this paper, Bayesian non-parametric estimators for entropy and extropy with possibly right censored data are proposed. The approach uses the beta-Stacy process as prior distribution. Examples are presented to illustrate the performance of the estimators.

Keywords: Beta-Stacy process, entropy, extropy, non-parametric Bayesian statistics, right censored data.
Mathematics Subject Classification (2010): 94A17, 62F15, 94A15.

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A Monte Carlo EM Algorithm for Fitting ARMA Models to Censored Time Series

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Abstract:
Censored time series arise commonly in environmental and meteorological applications when measurements fall below detection limits. Fitting Gaussian ARMA models is challenging due to an irregular observed-data likelihood. **?** proposed a simulation-based EM-like procedure that imputes censored values from their conditional truncated Gaussian distribution. While effective, this estimator often exhibits high Monte Carlo variability and unstable convergence under severe censoring. We introduce a Monte Carlo averaged variant: at each iteration, multiple independent stochastic updates are averaged, reducing estimator variance. Our method collapses to the original procedure when the number of averaged updates equals one. Simulation studies across several ARMA models show improved stability and accuracy, especially under heavy censoring.

Keywords: Censored time series, ARMA models, Truncated multivariate normal, EM-like estimation, and Monte Carlo averaging.
Mathematics Subject Classification (2010): 62M10, 83C75, 65C05.

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Expectation-Maximization Algorithm for Efficient Optimization of Multi-Response Bridge Regression

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Abstract:

Optimizing multi-response bridge regression using conventional methods like Newton-Raphson is computationally expensive and sensitive to initialization. This paper proposes a novel Expectation-Maximization (EM) algorithm for optimizing the multi-response bridge objective. By interpreting the Generalized Gaussian prior as a Gaussian Scale Mixture, we derive an iterative reweighted least squares procedure with a straightforward M-step. Numerical experiments show that EM outperforms Newton-Raphson in most cases. The two methods give similar sparsity patterns. However, EM achieves lower prediction error on average.

Keywords:
EM algorithm, Multi-response, Penalized regression, Feature selection.

Mathematics Subject Classification (2010): 62J05, 62J12

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Two-Parameter Ridge Estimation in Seemingly Unrelated Regression Models

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Abstract:
Seemingly Unrelated Regression (SUR) models are used when several linear regression equations are investigated simultaneously. To reduce the impact of multicollinearity in SUR models, the one-parameter ridge (Ridge-1) estimator has been proposed. As a generalization, this paper introduces the two-parameter ridge (Ridge-2) estimator for SUR models with multicollinearity. The performance of the proposed estimator is compared with Generalized Least Squares (GLS) and Ridge-1 via simulations. A real dataset on chronic renal failure is used for illustration. The results show that the Ridge-2 estimator outperforms both GLS and Ridge-1 under severe multicollinearity.
Keywords: Multicollinearity, One-parameter ridge, Seemingly unrelated regression, Two-parameter ridge, Mean squared error.
Mathematics Subject Classification (2010): 62J07, 62J05.

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E-Bayesian Estimation for Exponential Distribution under Progressive Type II Censoring with DeGroot Loss Function

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Abstract:
This paper investigates E-Bayesian estimation for the parameter of the exponential distribution under the DeGroot loss function based on progressively Type-II censored data. We consider two scenarios: (i) when the sample size is fixed, and (ii) when the sample size is random. A simulation study verifies that a random sample size may lead to improvement in terms of estimated risk.
Keywords: DeGroot loss function, E-Bayesian estimation, Random sample size, Progressive Censoring, and Estimated risk.
Mathematics Subject Classification (2010): 62F10, 62N02.

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E-Bayesian Estimation for the Lomax Distribution Under the Precautionary Loss Function Based on Record Values

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Abstract:
This paper addresses E-Bayesian estimation of the Lomax distribution parameter within the framework of the precautionary loss function, using upper record values. The E-posterior risks of the proposed estimators are derived. A simulation study is carried out to compare and evaluate the estimators. A simulated data example is also given. The paper concludes with a discussion.
Keywords: Precautionary loss function, E-Bayesian estimation, Upper record values, and E-posterior risk.
Mathematics Subject Classification (2010): 62F10.

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Weighted Total Variation Distance for Copula-Based Dependency Analysis

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Abstract:
Total Variation Distance (TVD) has been recently introduced as a copula-based dependency measure. Despite its useful properties, the standard TVD treats all regions of the copula space equally, which limits its ability to focus on specific dependence structures such as tail dependence. This paper proposes a weighted version of TVD, called Weighted Total Variation Distance (wTVD), which incorporates a non-negative weighting function that integrates to one. Theoretical properties, including boundedness, symmetry, and invariance under monotonic transformations, are established. A nonparametric estimator based on the Local Likelihood Probit Transformation method is presented. Simulation studies demonstrate that wTVD can effectively distinguish between different types of tail dependencies where the standard TVD fails to do so.
Keywords: Copula, Total Variation Distance, Weighted Total Variation Distance, Tail dependence.
Mathematics Subject Classification (2010): 62H05, 62H20.

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Applying inverse sampling to simultaneous estimation of the population size and total

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Abstract:
This article addresses the problem of estimating the population total τ_y when the population size N is unknown. The importance of this issue becomes more apparent when the capture–recapture methods based on fixes-size sampling designs provide negatively-biased estimates of both mentioned parameters. To handle this problem, we consider the inverse-recapture sampling (with and without replacement) and find unbiased estimators for (N,τ_y) in the situations where the appropriate capture sample is available or not. Finally, a theoretical comparison between the estimators is presented and a brief simulation study is conducted to compare the introduced estimators.
Keywords: Capture-recapture, Hansen-Hurwitz estimator, Horvitz-Thompson estimator, Inverse sampling, Population total.
Mathematics Subject Classification (2010): 62D05, 62F10, 62G05.

Covariance Estimation Strategies in Massive Spatial and Spatial-Temporal Data

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Abstract:
Covariance plays very important roles in modelling and in prediction of spatial data. For instance, many statistical inferences such as maximum likelihood estimation and best linear unbiased prediction involve covariance matrices which must be inverted and this evaluation is slow when the number of observations is large, and the complexity increases even further in a space-time context. First, we addresses a Bayesian grouping-based approach, extending Vecchia's approximation and relying on the conditional independence assumption of ordered data which significantly reduces computational burden in nonparametric estimation of a nonstationary spatial covariance. Next, we propose *half spectral composite likelihood* for the estimation of spatial-temporal covariances which involves a spectral approach in time and a covariance function in space. The approach requires no matrix inversions and the estimators are shown to be consistent and asymptotically normal under increasing domain asymptotic. Examples are given using simulated and real data.
Keywords: Half-spectral model, Composite Likelihood, Whittle likelihood, Vecchia approximation
Mathematics Subject Classification (2010): 60M30, 62M11, 62M30, 62H11.

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Spatial Multi-Objective Optimization for Efficient Rain Gauge Network Design in Khuzestan, Iran

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Abstract:
Reliable rainfall monitoring is fundamentally linked to the strategic placement of rain gauge stations; however, many existing networks lack a systematic spatial design. This study introduces a spatial bi-objective optimization framework to evaluate the current rain gauge network in Khuzestan Province, Iran, and to define optimal configurations for future network expansion or restructuring. A novel Hybrid AMOSA_NSGA-II algorithm is utilized to navigate the trade-off between two competing objectives: minimizing the root mean total error of rainfall predictions and minimizing the number of stations to reduce operational costs. The results demonstrate that optimized configurations with fewer stations consistently outperform the current network in predictive accuracy. These findings highlight the critical role of spatial optimization in developing cost-effective, high-performance rainfall monitoring systems.
Keywords: Rain gauge station network, Multi-objective optimization, HAN algorithm, Spatial data, Kriging.
Mathematics Subject Classification (2010): 62H11, 90C29, 62P12.

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Bayesian Local Sensitivity to Non-ignorability with General Missingness of Outcomes and Covariates

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Abstract:
A major concern in statistical analysis is missing data. Analysis frequently operates under the presumption that missingness is ignorable when it occurs in the study. It is critical to evaluate the effect of missingness on the most important Bayesian inferences because ignorability is an untestable assumption in the absence of data augmentation. Previously, in a Bayesian framework, the influence of missing outcomes' non-ignorability was studied using local sensitivity indices. In this paper, for the first time, the Bayesian index of local sensitivity to non-ignorability for data exposed to general missingness in outcome and covariates will be extended. My results indicate that the Bayesian estimates of parameters of interest via local sensitivity approximation are more accurate than complete-case analysis and ignorable model. I will evaluate the features of my proposed indices through several simulated studies.
Keywords: Local Sensitivity to Non-ignorability, General Missingness, Bayesian Approach, and Local Sensitivity Indices.

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Constructing a High Frequency Online Consumer Price Index for Iran Using MIDAS Models

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Statistical Research and Training Center

Abstract:

This paper proposes a modern methodological framework for constructing a high frequency Consumer Price Index (CPI) for Iran using online price data combined with official monthly CPI information. The approach integrates automated web scraped prices from major Iranian e commerce platforms with official item weights and employs Mixed Data Sampling (MIDAS) regressions to nowcast and forecast the monthly CPI. Results demonstrate that MIDAS models effectively translate high frequency online price movements into accurate signals of monthly inflation, improving timeliness and robustness relative to traditional methods. The study provides a replicable pipeline for real time inflation monitoring in data constrained environments.

Keywords: Consumer Price Index,MIDAS regression,online prices,nowcasting,inflation

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An Adaptive Hybrid Active-Passive Learning Strategy for Statistical Representativeness: A Case Study of Breast Cancer Diagnosis

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[2]**Razi University**

Active learning reduces the cost of supervised learning by selecting informative observations for labeling, yet the resulting samples often lack statistical representativeness, leading to biased estimates of population parameters such as disease prevalence. In this study, we propose an adaptive hybrid strategy that initially employs margin-based sampling to rapidly improve predictive accuracy and then switches to simple random sampling once a predefined accuracy threshold is reached, thereby preserving the representativeness of the labeled sample. The proposed method is evaluated on the Wisconsin Breast Cancer dataset using a Random Forest classifier. Monte Carlo experimental results demonstrate that the hybrid strategy achieves predictive performance comparable to that of pure active learning while substantially improving the statistical representativeness of the labeled sample, thus providing a reliable foundation for valid statistical inference alongside high classification accuracy.

Keywords: Active learning, Hybrid learning, Random Forest, Statistical inference, Breast cancer diagnosis.
Mathematics Subject Classification (2020): 62H30, 62D05, 68T05.

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A Hybrid Control Chart Based on CUSUM and Double Moving Average

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Abstract:

Quality assurance in industries is not possible without continuous monitoring and rapid detection of unwanted shifts in the process mean. In this paper, a new hybrid control chart, as DMA-CUSUM, is designed which is a combination of the Double Moving Average and CUSUM control charts. The performance of the proposed control chart is evaluated against the Double Moving Average and Moving Average-Cusum control charts using two criteria: the average run length and the median run length. The findings indicate that the proposed control chart performs superiorly in detecting small-to-moderate shifts in the process mean, particularly by choosing the appropriate width.

Keywords: Statistical quality control, Double moving average, CUSUM chart, Average run length, Median run length, Monte Carlo simulations.

Mathematics Subject Classification (2010): 62P30.

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BehaveSeg: A Behavior-Aware Multi-Algorithm Framework for Intelligent Customer Segmentation

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[2]**Department of Computer Science, Yazd University, Yazd, Iran**

Abstract:
Customer segmentation remains a cornerstone of personalized marketing, yet conventional methods frequently fall short in capturing dynamic behavioral patterns due to their reliance on static demographic or transactional data. This study introduces BEHAVESEG, a behavior-aware pipeline that integrates rich behavioral feature engineering, Principal Component Analysis (PCA) dimensionality reduction, and a comprehensive multi-algorithm clustering approach. Seven widely used clustering algorithms were systematically evaluated using Silhouette Score, Davies–Bouldin Index, and Calinski–Harabasz Index, with the first seven PCA components preserving 92.2% of behavioral variance. Results demonstrate that K-Means achieved superior performance (Silhouette = 0.3430, Calinski–Harabasz = 1028.29), yielding three well-separated and interpretable customer segments. These profiles provide actionable insights for targeted marketing, customer retention, and revenue optimization strategies.
Keywords: Customer Segmentation, Clustering Analysis, Behavioral Analytics, Unsupervised Learning
Mathematics Subject Classification (2010): $62\text{H}30, 68\text{T}05, 91\text{B}42, 62-07$.

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Optimal lot reinspection based on truncated life test for logistic Rayleigh distribution

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Abstract:

Single sampling scheme is a conventional method for evaluating the equality of lots of products. Repetitive sampling plans are introduced in order to reduce the size of samples drawn from the lot. The product lifetime follows the logistic Rayleigh distribution. Best repetitive sampling plans are determined by minimizing the sampling effort using integer nonlinear programming. In terms of average sample number, optimal repetitive sampling plans outperform single sampling plans. A practical application is included for illustrative purposes.

Keywords: Quality control, Repetitive sampling plans, Average sample number, Producer and Consumer risks.

Mathematics Subject Classification (2010): 62N05, 62P30.

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Construction and Analysis of a Nonstandard Finite Difference Scheme for Stochastic Partial Differential Equations

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Abstract:
This paper is devoted to the development and comprehensive analysis of a nonstandard finite difference (NSFD) scheme for Itô stochastic partial differential equations (SPDEs). The qualitative properties of the proposed scheme, including consistency, stability, and convergence, are thoroughly investigated. Numerical simulations are presented to demonstrate the accuracy and computational efficiency of the proposed scheme.
Keywords: Nonstandard finite difference scheme, consistency, stability, convergence, stochastic partial differential equations.
Mathematics Subject Classification (2010): 65M06, 65M12, 60H15.

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On the Zero-Inflated Geometric INAR(1) Process with Random Coefficient

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Abstract:
Count time series with overdispersion, excess zeros, and autocorrelation frequently arise in hydrology, epidemiology, and climatology. However, INAR processes with random coefficients have received limited attention, and non-random coefficient models often fail due to ignored random effects. Moreover, neglecting zero inflation causes overdispersion and biased estimates. This paper examines the zero-inflated geometric INAR(1) process with random coefficient (ZIGINAR$_{RC}(1)$), synthesizing its probabilistic properties, Whittle estimation, sieve bootstrap methods, and Bayesian forecasting. Simulation results show Bayesian prediction achieves superior accuracy, while sieve bootstrap offers good performance with reasonable efficiency. Practical applicability is demonstrated using animal health submission data.
Keywords: Count time series, Zero-inflation, Random coefficient, Estimation methods, Forecasting.
Mathematics Subject Classification (2010): 62M10, 62F10, 62M20.

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Bayesian Inference for Matrix-Variate Gaussian Distributions: Theory, Computation, and Applications

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Abstract:
We develop a fully Bayesian framework for matrix-variate Gaussian distributions with Kronecker-structured covariance $\Psi \otimes \Sigma$, including conjugate priors, Gibbs sampling full conditionals, and sparsity-inducing extensions for high dimensions. The inherent scaling identifiability issue $(\Psi \otimes \Sigma) = (c\Psi) \otimes (c^{-1}\Sigma)$ is addressed via the constraint $\mathrm{tr}(\Sigma) = p$, though simulations reveal asymmetry when $p \neq q$. Increasing sample size from $n = 30$ to $n = 100$ reduces relative Frobenius error by 55% for dimensions $p, q \leq 10$.
Keywords: Bayesian inference, Gibbs sampling, Kronecker covariance, Matrix-variate Gaussian. **Mathematics Subject Classification (2010):** 62F15, 62H12, 62J07.

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Bayesian Structure Learning of Gene Expression Networks via Laplace-Approximated Scoring: An Application to TCGA Breast Cancer Data

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Abstract:
Breast cancer is a heterogeneous disease driven by complex molecular interactions. Identifying direct dependencies between continuous gene expression profiles and discrete clinical outcomes is critical to robust biomarker discovery. In this study, we present an empirical application of a recently developed Bayesian directed acyclic graph (DAG) learning framework to infer probabilistic dependency networks from the TCGA Breast Cancer dataset. The proposed framework utilizes a DAG-Probit model, treating the binary clinical status as a thresholded latent Gaussian variable. By leveraging Laplace approximations to efficiently estimate node-wise marginal likelihoods and employing Markov chain Monte Carlo (MCMC) sampling for high-dimensional structure exploration, the model successfully infers a sparse, clinically relevant regulatory network. The application identifies key driver genes—such as *COL11A1*, *PCOLCE2*, and *SFRP1*—with a posterior edge inclusion probability (1.00), demonstrating the effectiveness of the framework for biological interpretation and mechanistic oncology studies.

Keywords: Bayesian Structure Learning, Breast Cancer Data, DAG-Probit Model, Gene Regulatory Networks, Mixed Data.
Mathematics Subject Classification (2010): 62P10, 62F15, 62H22.

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Beyond 1D Heuristics: Temporal-Causal Calibration and Multivariate Non-Parametric Hypothesis Testing for Uncertainty Quantification in Retrieval-Augmented Language Models

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Abstract:
Most methods for measuring how confident a language model should be rely on a single number, predictive entropy, which is too simple to capture what really happens when a model's built-in knowledge conflicts with facts from an external source. We propose the Temporal-Causal Calibration (TCC) framework, which measures *parametric stubbornness* - how strongly a model clings to old knowledge when new evidence disagrees with it, using tools from causal inference. We then use statistical hypothesis tests to check whether the model's uncertainty scores are trustworthy. Tested on two small, locally run models, TCC-UQ achieves an AUROC of 0.4895 and an Expected Calibration Error (ECE) of 0.1337, using only 2.1 MB of extra memory. Kolmogorov-Smirnov tests ($D = 0.713$, $p \approx 4.90 \times 10^{-37}$) and paired t-tests ($t = -64.48$, $p \approx 9.66 \times 10^{-111}$) confirm that TCC-UQ produces a statistically distinct confidence distribution from the uncalibrated baseline. The results demonstrate that causal grounding of stubbornness measurement yields interpretable, statistically verifiable uncertainty signals, while also revealing important limitations that motivate future work.

Keywords: Retrieval-Augmented Generation; Uncertainty Quantification(UQ); Calibration; Non-Parametric Testing; Causal Inference.

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High-Resolution Spectral Estimation of Univariate and Multivariate Stationary Time Series

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Abstract:

This study evaluates spectral density estimation techniques for stationary time series, with an emphasis on high-resolution methods. Classical approaches often have difficulty resolving closely-spaced frequency components when data is limited. Through controlled simulations, we compare these traditional techniques against high-resolution estimators and show that the latter consistently deliver clearer, more distinct frequency estimates. The methods are also extended to multivariate time series, demonstrating their practical value in complex signal characterization.

Keywords:

Stationary time series, Spectral density, Capon's estimate, High resolution estimate, Block-Toeplitz matrix, Periodogram.

Mathematics Subject Classification (2010): 62M15, 62G07, 15B05.

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Deep Learning–Based Competing Risks Survival Analysis for Predicting Cause-Specific Mortality in Heart Failure Patients

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Abstract:
Heart failure (HF) patients face multiple competing causes of death, making standard survival models prone to bias. We developed a deep learning–based competing risks (DLCR) model to predict cause-specific mortality in a retrospective cohort of 364 HF patients from a tertiary cardiovascular center in Iran. After a five-year follow-up, 160 patients died of HF and 97 of other causes. The DLCR model achieved a concordance index (C-index) of 0.71 for HF-related mortality and 0.81 for non-HF mortality, with an integrated Brier score (IBS) of 0.16 and 0.09, respectively. The model captured distinct temporal risk patterns: HF-related deaths dominated the first 35 months, after which other-cause mortality gradually exceeded HF mortality. Our findings demonstrate that explicitly accounting for competing risks via deep learning improves risk stratification accuracy. The DLCR framework offers a promising tool for personalized prognosis in HF, although external validation in multi-center cohorts is needed before clinical deployment.

Keywords: Deep learning, Competing risks, Survival analysis, Heart failure, Cause-specific mortality, Predictive modeling.
Mathematics Subject Classification (2010): 62N01, 62N02, 92C50.

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A Hybrid FCNN–LSTM Framework for Sequential Prediction with Application to Air Pollution Forecasting

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Abstract:
Accurate prediction of sequential data is challenging due to complex nonlinear relationships and temporal dependencies. Fully Connected Neural Networks (FCNNs) effectively capture nonlinear feature interactions but cannot explicitly model temporal patterns, whereas Long Short-Term Memory (LSTM) networks are suitable for sequential learning but may inadequately represent complex feature relationships. This study proposes a hybrid FCNN–LSTM framework that combines nonlinear feature extraction with temporal sequence modeling. The FCNN component learns latent feature representations, while the LSTM component captures dynamic temporal dependencies. The proposed framework is evaluated on an air pollution prediction task using real-world environmental data. Experimental results show that the hybrid model consistently outperforms standalone FCNN and LSTM models across multiple evaluation metrics, demonstrating superior predictive accuracy and generalization capability.
Keywords: Fully Connected Neural Networks, Long Short-Term Memory Networks, Sequential Data, and Temporal Dependency
Mathematics Subject Classification (2010): 92B20, 62M20.

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The Critical Role of Feature Engineering in Time-Series Prediction: A Case Study on Air Pollution Forecasting

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Abstract:
Feature engineering plays a crucial role in improving the predictive performance of machine learning models for time-series forecasting. This study investigates the impact of engineered temporal features on air pollution prediction using a dataset containing atmospheric pollutants and meteorological variables. A comprehensive feature engineering framework was developed, including lag variables, rolling statistics, cyclical time encodings, and pollutant–weather interaction features. The effectiveness of the proposed features was evaluated using the Random Forest and Light Gradient Boosting Machine (LightGBM) models. Forecasting performance was compared before and after feature engineering for multiple pollutants, including CO, O3, NO2, and SO2. Results showed substantial improvements across all prediction tasks, demonstrating the ability of the derived features to capture temporal dependencies, seasonal patterns, and nonlinear environmental interactions. The results highlight the pivotal role of feature engineering in time-series forecasting and demonstrate that substantial accuracy improvements can be achieved without modifying the underlying learning algorithm.
Keywords: Time-series Forecasting, Feature engineering, Random Forest, and Light Gradient Boosting Machine.
Mathematics Subject Classification (2010): 92B20, 62M20.

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Extropy of the Residual Lifetime of Alive Components in Coherent Systems

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Abstract:

This research investigates the uncertainty associated with the remaining lifetimes of alive components in coherent systems after system failure. Although the system may no longer function, some components may still remain alive, and the uncertainty in their remaining lifetimes can be meaningfully quantified. To this end, we employ extropy as a measure of uncertainty for the remaining lifetimes of alive components. By combining the system signature with conditional properties of order statistics, we develop a mathematical framework for this purpose. Focusing on the heavy-tailed Lomax distribution, our results provide insight into how the system structure affects the uncertainty of the remaining lifetimes of alive components after system failure.

Keywords: Extropy, Coherent System, Order statistics, System signature, Residual lifetimes of live components.

Mathematics Subject Classification (2010): $62N05$; $62F10$.

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Toward Intelligent Optimal Sampling: Adaptive Monte Carlo Tree Search for Graphical Sampling Designs

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Abstract:
Graphical finite-population sampling represents prescribed first-order inclusion probabilities as bars on a unit interval. Exchanging equal-length segments between bars preserves the inclusion probabilities and fixed sample size while changing the induced sampling design and its second-order inclusion probabilities. The original optimal graphical sampling procedure searched this design space using a memory-bounded greedy best-first search. We develop an adaptive multi-start Monte Carlo tree search that combines upper-confidence selection, mutations at several scales, parallel local rollouts, and restarts from the incumbent design after stagnation. The methods are compared on 18 scenarios formed from the MU284 municipal data, three optimization variables, three variables used to construct inclusion probabilities, and two sampling fractions. Relative to greedy best-first search, the proposed method reduced exact Narain–Horvitz–Thompson variance in 13 of 18 optimization-variable comparisons and 10 of 18 study-variable comparisons. Median relative efficiencies were 104.7 and 100.3, respectively, with comparable computation times. The results show that adaptive tree search can improve exploration of the graphical design space, although no method dominates in every scenario.
Keywords: finite-population sampling; inclusion probabilities; intelligent search.

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Machine Learning Methods for Bivariate Integer-Valued Time Series Data

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Abstract:
In this paper, we approach the problem through a machine learning framework, focusing on time series data particularly integer-valued observations without resorting to classical statistical analysis. First, we introduce four machine learning techniques. Then, the procedure will be examined, and assessing their predictive accuracy using mean absolute error. In application, this study analyze a count time series dataset using machine learning techniques. Our results highlight the strengths of the approach and provide insights for model selection in count time series applications.
Keywords: Machine learning techniques,Cross-validation,Bivariate integer-valued autoregressive models,Over-dispersion
Mathematics Subject Classification (2026): Machine Learning

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Regularized Multivariate Two-way Functional Principal Component Analysis

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Abstract:
Functional principal component analysis is a fundamental tool for dimension reduction in functional data, but classical estimators may produce noisy and difficult-to-interpret components when the data are high-dimensional, multivariate, or structured along two domains. We propose a regularized multivariate two-way FPCA framework based on penalized rank-one matrix approximation. The method imposes smoothness and sparsity on both the left and right singular vectors, allowing joint regularization of score and loading directions. The multivariate loading direction is regularized through block-diagonal roughness penalties and variable-specific thresholding operators, while the row direction can be regularized when observations themselves lie on a structured domain. Conditional generalized cross-validation and K-fold cross-validation are used to select smoothing and sparsity parameters. Simulations, a chessboard illustration, and wearable-sensor data show that the proposed approach yields low-rank, denoised, and interpretable components compared with unregularized SVD and one-way regularized alternatives.
Keywords: Functional principal component analysis, multivariate functional data, two-way functional data, regularized SVD, smoothness, sparsity.
Mathematics Subject Classification (2010): 62H25, 62R10, 62G08.

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Statistical Analysis of Temporal Changes in Complete Blood Count Parameters Before, During, and After the COVID-19 Pandemic: A Hospital-Based Study in Damghan, Iran

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Abstract:
The COVID-19 pandemic has been associated with various physiological changes extending beyond its respiratory manifestations. This study aimed to statistically compare complete blood count (CBC) parameters among patients referred to Velayat Educational, Research and Treatment Center in Damghan, Iran, before the pandemic (2018), during the pandemic (2020), and after the pandemic (2023). This descriptive–analytical cross-sectional study was conducted using secondary laboratory data extracted from the Hospital Information System (HIS). All eligible records were included using a census approach. Descriptive statistics and one-way analysis of variance (ANOVA) were applied to evaluate temporal differences in hematological parameters. Significant differences were observed in several CBC indices across the three study periods. Platelet count and lymphocyte percentage decreased during the pandemic and showed partial recovery in the post-pandemic period. Significant temporal variations were also identified in red blood cell count (RBC), hemoglobin (Hb), hematocrit (Hct), mean corpuscular volume (MCV), mean corpuscular hemoglobin concentration (MCHC), and white blood cell count (WBC). Although most mean values remained within normal laboratory reference ranges, the observed changes indicate measurable population-level shifts in hematological parameters during and after the COVID-19 pandemic. These findings demonstrate the usefulness of routine CBC data for statistical monitoring of population health trends during large-scale public health events.

Keywords: COVID-19,Platelet Count,Statistical Analysis,Hemoglobin,T Test,Hematological Parameters,ANOVA,Complete Blood Count,Lymphocyte
Mathematics Subject Classification (2010): $62-XX$.

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Shrinkage Estimations of Semi-parametric Models for High-Dimensional Data in Finite Mixture Models

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Abstract:

This paper proposes a novel enhancement to semi-parametric models by integrating shrinkage to improve the predictive accuracy and performance of Ridge and ecpc models. By employing the EM algorithm, updated parameter estimates are derived, demonstrating significant error reductions in metrics such as Mean Squared Error (MSE), Sum of Squared Errors (SSE), and Geometric Mean Squared Error (GMSE). Extensive simulation studies reveal consistent improvements in model performance, with shrinkage enhancing accuracy and robustness across various scenarios. The findings highlight the potential of shrinkage in refining semi-parametric models, offering a more accurate framework for statistical predictions. This study paves the way for future research into applying shrinkage techniques to diverse data types and model structures, setting a benchmark for model optimization in statistical analysis.

Keywords: Semi-parametric models,shrinkage estimations,high-dimensional data,finite mixture models

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Incorporating Random Effects into Extreme Learning Machine with Ridge Regularization

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Abstract:
Extreme Learning Machine (ELM) is a fast and efficient method for modeling nonlinear relationships; however, it may suffer from instability and overfitting in high-dimensional settings. In addition, ELM does not inherently account for correlated or hierarchical structures that are common in real-world data. In contrast, Linear Mixed Models (LMM) are designed to handle such dependencies through random effects. In this study, a hybrid framework is proposed by integrating ELM and LMM, where ELM models nonlinear fixed effects and LMM captures random effects and group-level variability. This combination enables simultaneous modeling of nonlinear relationships and hierarchical structures within a unified framework. The proposed approach is evaluated using the Boston Housing dataset, demonstrating its effectiveness for structured regression problems

Keywords: Linear Mixed Model,Extreme Learning Machine,Random Effect,Fixed Effects,Ridge
Mathematics Subject Classification (2010): $62-XX$.

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Efficient MCP-Penalized Variable Selection for Time-Dependent Cox Models with Counting-Process Data

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Abstract:
This paper proposes an MCP-penalized approach for variable selection in time-dependent Cox regression models with counting-process data. The proposed algorithm enables efficient estimation in moderate- and high-dimensional settings. Simulation results show that MCP substantially reduces false negatives and is computationally more efficient than LASSO. An analysis of the Mayo Clinic PBC dataset further demonstrates that MCP achieves predictive performance comparable to LASSO while requiring less computation time and producing less shrinkage of important covariate effects.

Keywords: Time-Dependent Cox Model, Minimax Concave Penalty (MCP), Variable Selection, and Counting-Process Data.

Mathematics Subject Classification (2010): 62N02, 62J07, 62J12.

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A Robust FSVM-GARCH Framework for Imbalanced Time Series Data

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Abstract:
This paper presents an enhanced fuzzy support vector machine (FSVM) framework tailored for financial time series classification. We address the persistent challenges of noise and class imbalance by introducing a novel integration of domain-based volatility information and adaptive fuzzy weighting. The key innovation lies in incorporating the Parkinson volatility estimator—a highly efficient and model-free variance measure—as the sole input feature, ensuring robustness in environments where high-frequency data are unavailable. Furthermore, we develop a weighted fuzzy membership mechanism (WFSVM) that assigns membership values based on inverse class frequency weighting and volatility-based distance metrics. This dual mechanism significantly enhances the classifier's performance, allowing it to outperform standard SVM and state-of-the-art imbalance-corrected models in volatility regime recognition, especially under skewed data distributions.
Keywords: Fuzzy Support Vector Machine (FSVM), Class Imbalance Learning (CIL), Parkinson Volatility Estimator, Volatility Clustering, Mahalanobis Distance
Mathematics Subject Classification (2010): 62H30, 91G70, 68T10.

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On the Asymptotic Properties of Liu Estimator

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Abstract:
In traditional regression analysis, ordinary least-squares estimation is the optimal approach for deriving regression weights, provided that the fundamental assumptions are satisfied. Nevertheless, if the data fail to meet certain assumptions, the findings may be deceptive. Outliers particularly contravene the assumption of regularly distributed residuals in least-squares regression. Therefore, it is essential to employ estimating techniques specifically formulated to address these issues. In this paper, the Liu estimator and its robust type are introduced in the semiparametric linear model when the error terms are not independent and some linear constraints are assumed to combat the presence of multicollinearity and outlier challenges. In the literature on Liu methodology, the obtaining of biased parameter plays an important role in model prediction and estimation. Based on a set of observations with a sample size of n, and the integer trimming parameter $h \leq n$, the LTS estimator computes the hyperplane that minimizes the sum of the least h squared residuals. Even though LTS estimator is statistically more effective than the widely used least median squares (LMS) estimate, it is less complicated computationally than LMS. Hereby we propose the robust estimators for the biasing parameter of Liu estimation based on the improved LTS obtained by semidefinite programming approach. Asymptotic normality of proposed robust Liu estimators under some conditions is also proved and a robust test is given for testing the symmetry hypothesis $H_0 : \boldsymbol{R\beta} = \boldsymbol{r}$. It is shown that these estimators perform better than classical Liu estimator. For our proposal, via a Monte-Carlo simulation and a real data example, performance of the Liu type of robust estimators are compared with the classical ones in restricted partially linear models.

Keywords: Breakdown point, Least trimmed squares estimator, Linear restriction, Multicollinearity, Outlier, Semidefinite programming, Semiparametric regression models
Mathematics Subject Classification (2010): 62J20, , 62G35.

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Multivariate Tail Conditional Expectation Under a Linear Constraint: A New Risk Measure for Aggregated Exposures

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Abstract:
Most multivariate tail risk measures, such as the multivariate tail conditional expectation (MTCE), assume that all risk factors exceeds their marginal quantiles simultaneously. But, in real word, this assumption sometimes is unrealistic, since systemic events are typically generated by a linear combination of risk factors crossing a critical threshold. So, in this paper, we propose a new risk measure called the multivariate tail conditional expectation under a linear constraint (MTCE-LC). This new risk measure captures the expected risk conditional on a weighted sum of risk factors exceeding a high quantile, so that weakness in one risk factor can be offset by strength in another. This measure can be a good tool for stress testing and capital allocation in systemic risk management. We present an exact expression for the proposed measure under multivariate normal risk factors and also, we carry out a Monte Carlo simulation study to show the accuracy of the theoretical results.

Keywords: Tail conditional expectation, Multivariate risk measure, Linear constraint, Systemic risk, Multivariate normal distribution.
Mathematics Subject Classification (2010): 62H10, 60E05.

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Application of copula theory in 6G wireless communications

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Abstract:

The emergence of sixth-generation (6G) wireless networks has introduced new challenges in accurately modeling complex dependencies and correlation structures in wireless propagation environments. Among the promising technologies envisioned for 6G, the Fluid Antenna System (FAS) has attracted significant attention due to its ability to dynamically reposition antenna elements within a confined space, thereby enhancing communication reliability and mitigating fading effects. The performance of FAS, however, is strongly influenced by the spatial correlation among different antenna locations, making accurate dependence modeling a critical research problem. This work introduces Copula theory as a powerful statistical framework for modeling dependence structures beyond conventional linear correlation measures. After reviewing the fundamentals of copulas and their key properties, we demonstrate how copula-based models can capture complex spatial dependencies in wireless channels more accurately than traditional correlation-based approaches. Particular emphasis is placed on the application of copulas to characterize spatial correlation in Fluid Antenna Systems and to analyze their impact on system performance metrics such as outage probability, diversity gain, channel capacity, and antenna position selection strategies. Finally, the presentation discusses the opportunities and challenges of integrating copula-based dependence modeling into future 6G wireless communication systems and highlights several promising directions for further research.

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Method for Estimating Genotype Stability, Adaptability, and Environmental Discrimination in Plant Breeding Programs

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Abstract:
Breeding programs aim not only to improve crop performance but also to ensure stability and adaptability across diverse environments. Evaluating genotype resilience requires understanding both general adaptability ability (GAA), the mean trait performance across multiple environments, as well as specific adaptability ability (SAA), the deviation of a genotype in a particular environment. A comprehensive approach for assessing GAA, SAA, and genotype stability, is presented for integrating both linear and nonlinear responses to environmental variation. The method relies on multi-environment trials, partitioning phenotypic variance into genotype, environment, and genotype $\times$ environment interaction components using ANOVA models, and calculating stability indices such as the relative stability and stability value of genotypes (SVG). This framework allows breeders to select genotypes with optimal performance while maintaining stability, balancing trade-offs between high mean trait values and environmental sensitivity. Furthermore, it provides insights into environmental differentiation and the compensatory or destabilizing effects of genotype $\times$ environment interactions. By combining theoretical and practical aspects of adaptive breeding, this approach offers a robust tool for guiding selection strategies that enhance both productivity and resilience in crop populations. To compare populations and select appropriate breeding methods across different environments, a technique is introduced to partition the phenotypic variance of a population into GAA and SAA variances.
Keywords: Adaptability ability, Stability value, Genotype $\times$ environment interaction.
Mathematics Subject Classification (2010): 62P10, 62J10, 62K10, 92D10.

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Application of Best Linear Unbiased Prediction (BLUP) in Stability Analysis and Genotype × Environment Interaction Studies

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Abstract:
Genotype × environment interaction (GEI) is a major challenge in plant breeding, as it complicates the identification of genotypes that are both high-performing and stable across diverse environments. Multienvironment trials (METs) generate complex datasets, often unbalanced and incomplete, where traditional ANOVA or regression-based stability metrics are limited. Best Linear Unbiased Prediction (BLUP), within a mixed model framework, provides a robust approach for estimating genotypic performance while accounting for random effects, environmental variation, and heterogeneous residuals. BLUP enables shrinkage-based predictions, improving accuracy over raw means or BLUE, particularly in unbalanced datasets. Furthermore, incorporation of pedigree or marker-derived relationship matrices allows exploitation of genetic correlations, enhancing prediction of untested genotypes and facilitating genomic selection. BLUP-based methods can also quantify stability through variance of predicted genotypic values across environments, factor-analytic decomposition of G × E, and reliability-adjusted indices, providing actionable insights for selection. This manuscript reviews theoretical foundations, practical implementation, and computational approaches for BLUP in METs, including hierarchical and factorial designs. It also discusses integration with factor-analytic models for complex GEI, the use of combined pedigree and marker information, and strategies for handling missing data. BLUP-based stability analysis represents a flexible and powerful tool for modern plant breeding, enabling selection of widely adapted and specifically adapted genotypes while maximizing genetic gain under diverse environmental conditions.
Keywords: Mixed models, Plant breeding, Multi-environment trials.
Mathematics Subject Classification (2010): 62P10, 62J12, 62H25, 92D10.

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Effective Analysis of Genetic Diversity of Plant Species through Artificial Intelligence Tools

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Abstract:
Genetic variation within species arises from complex interactions between evolutionary processes and environmental factors, often reflected in polymorphic patterns of Single-Nucleotide Polymorphisms (SNPs). Traditional landscape genetics approaches have primarily focused on either broad-scale or local-scale environmental effects, limiting the statistical inference of genetic diversity. In this study, we present a comprehensive statistical framework integrating supervised machine learning, convolutional neural networks (CNNs), and simulation-based modeling to quantify the influence of multiple factors on genetic variation. Supervised machine learning allows prediction of key genetic metrics, such as allelic richness and population differentiation, while simultaneously estimating the relative importance of environmental and historical drivers. CNNs process SNP alignments as high-dimensional data, extracting patterns without requiring predefined summary statistics or population assignments. Simulation-based approaches, including Approximate Bayesian Computation (ABC), enable robust estimation of parameter posteriors under complex evolutionary scenarios. By combining these methods, our framework captures both discrete and continuous genetic processes, models stochasticity in natural populations, and provides interpretable statistical measures of factor importance. This approach enhances inference across spatial and temporal scales, facilitating hypothesis testing and evolutionary interpretation. The framework also has practical applications for conservation planning and biodiversity management, allowing researchers to identify populations and environmental factors most critical for maintaining genetic diversity. This integrative, statistics-driven approach represents a significant advancement in molecular ecology, offering scalable, interpretable, and robust tools for analyzing genomic variation in natural populations.
Keywords: Supervised machine learning, Convolutional neural networks, Statistical genomics.
Mathematics Subject Classification (2010): 62P10, 62F15, 92D20, 92D15.

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Generalized Stress-Strength Reliability Model for Kumaraswamy Distribution

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Abstract:
This paper investigates the generalized stress-strength reliability model $R^G = P(Y < X < Z)$ when the random variables X, Y, Z follow the Kumaraswamy distribution. The Kumaraswamy distribution is a flexible lifetime model on the unit interval, widely used in hydrology, engineering, and survival analysis. Two scenarios are considered: a common first shape parameter α (with different second shape parameters β_i) and a common second shape parameter β (with different α_i). Maximum likelihood estimators (MLEs) of R^G are derived along with their asymptotic distributions. Bootstrap confidence intervals are constructed. A simulation study evaluates the finite-sample performance of the proposed estimators. Finally, a real data set on material strength is analyzed to illustrate the methodology.
Keywords: Kumaraswamy distribution, generalized stress-strength model, maximum likelihood, bootstrap, reliability.
Mathematics Subject Classification (2010): 62N05, 62F10, 62F40.

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A Fuzzy Spatio-Temporal Logistic Regression Model with Latent Skew-t Random Field

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Abstract:
Conventional spatio-temporal logistic regression models relying on Gaussian latent fields often impose restrictive assumptions of symmetry and light tails. Furthermore, they struggle to incorporate epistemic uncertainty, such as measurement imprecision, without relying on unverifiable distributional assumptions. To address these limitations, we propose a novel fuzzy spatio-temporal logistic regression model featuring a latent skew-t random field. Our approach leverages a Gamma scale-mixture to capture aleatory asymmetry and heavy tails, while employing fuzzy numbers to non-parametrically represent imprecision in covariates and parameters. We develop a Fuzzy Monte Carlo Expectation-Maximization algorithm for parameter estimation and establish its consistency. Comprehensive simulation studies demonstrate excellent parameter recovery, and an application to real-world data highlights the model's practical utility and enhanced predictive performance.

Keywords: Fuzzy spatio-temporal statistics, Logistic regression, Skew random field, FMCEM algorithm.
Mathematics Subject Classification (2010): 62H11, 62J12, 62M40.

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Least Angle Regression for Identifying Potential Predictors of HbA1c in Type 1 Diabetes: A Real-World Data Application

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Abstract:
Least Angle Regression (LARS) is an efficient variable selection method for high-dimensional data, offering computational advantages over traditional penalized regression approaches. This study applied LARS to predict short-term (six-month) and long-term (one-year) Hb A1c levels in 271 patients with type 1 diabetes using real-world data from the Sina health information system in Mashhad, Iran. The optimal models were selected using Mallows' Cp criterion at steps 13 and 20, respectively. Baseline Hb A1c and diabetic microvascular complications were the strongest positive predictors, while dietary factors, including fruit and dairy consumption, showed protective effects. LARS provided a parsimonious, interpretable framework for identifying key potential predictors of glycemic control in type 1 diabetes using real-world clinical data.
Keywords: Least Angle Regression,LARS,type 1 diabetes,HbA1c prediction,variable selection,penalized regression
Mathematics Subject Classification (2010): 62J07, 62P10, 62H30.

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Dependent Counting INAR(1) Process with Geometric Innovations: Estimation and Forecasting Methods

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Abstract:
This paper investigates estimation and forecasting methods for the DCINAR(1) model with geometric innovations (DCINARG(1)). Four estimation techniques are examined: modified conditional least squares, conditional maximum likelihood, Whittle estimation with tapered spectral version, and sieve bootstrap. For forecasting, three approaches are developed: conditional mean prediction, transition-probability-based median forecasting, and sieve-bootstrap prediction. Extensive simulations evaluate method performance. Application to a real dataset demonstrates the model's practical value and superior predictive accuracy.

Keywords: Count time series, Dependent thinning operator, Estimation, Forecasting, Sieve bootstrap, Whittle estimation.
Mathematics Subject Classification (2010): 62M10, 62F10, 62M20.

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Order Statistics in R: Moment Computation, Goodness-of-Fit Assessment, and Statistical Inference with the mos Package

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Abstract:
Although order statistics are fundamental in statistical inference, reliability analysis, and goodness-of-fit assessment, computational tools for their moment evaluation remain limited. In this paper, we briefly introduce the R package mos which provides a unified framework for the analysis of order statistics, censored samples, and k-record values. The package combines analytical evaluation of moments, whenever closed-form expressions are available, with Monte Carlo estimation for more general distributions. It also provides functions for variance, skewness, kurtosis, and efficient simulation of ordered-data structures. Applications to graphical goodness-of-fit diagnostics and best linear unbiased estimation illustrate the practical utility of the package. The mos offers a consistent and extensible environment for research and applications involving ordered data.
Keywords: Censoring, Order statistics, Moments, Record values, Reliability, R programming language.
Mathematics Subject Classification (2010): 62G30, 62-04, 62N05.

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Challenges and Opportunities for Transforming Education in the Age of AI

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Abstract: Generative AI is rapidly transforming education by changing how knowledge is accessed, understood, and applied. Traditional educational models based on memorisation and information delivery are becoming less effective in a world where AI systems can instantly generate information and support learning. This transformation presents both significant opportunities and major challenges for universities and educators. On one hand, AI can widen access to education, support personalised learning, reduce routine academic tasks, and enable educators to focus more on mentoring, creativity, and student development. On the other hand, it requires teachers to continuously adapt their pedagogical approaches and develop stronger technological and instructional skills.

This talk argues that AI should not be viewed merely as an additional technical skill, but as a transformative force reshaping the purpose and structure of education. Universities must move beyond producing graduates trained primarily in memorisation and standardised thinking, and instead prioritise critical thinking, innovation, collaboration, adaptability, and real-world problem-solving. The discussion also highlights the growing importance of lifelong learning and the need to develop human capabilities that AI cannot easily replicate.

Particular attention is given to the challenges faced by Iranian universities, especially limited access to the internet, international digital resources, and modern AI technologies. Without meaningful exposure to these tools, graduates risk falling behind global standards and losing international competitiveness. The talk further explores the importance of stronger collaboration between universities and industry as a practical strategy to reduce implementation costs and provide students with valuable real-world AI experience.

Ultimately, the talk concludes that universities must embrace AI responsibly while preserving their core mission as centres of independent thought, creativity, and intellectual development. By integrating AI effectively and ethically into teaching and learning, higher education can remain relevant, inclusive, and future-ready in an increasingly AI-driven world. If time permitted, I would also discuss some AI-related issues arising in my own modules, particularly concerning assessment design, student engagement, academic integrity, and the responsible use of AI tools in learning and teaching.

Keywords: Generative AI, higher education, educational transformation, lifelong learning, academic integrity.

Mathematics Subject Classification (2010): 68T05, 97C70, 97U50.

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Assessing Elevation Effects on Forest Spatial Patterns via Permutation Tests

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Abstract:
Introduction and Objective: In the analysis of spatial point processes, understanding whether environmental covariates affect not only intensity (density) but also second-order structure (clustering or regularity pattern) remains an underdeveloped research area. Most existing methods focus on intensity functions and assume second-order stationarity. This study presents a non-parametric permutation-based test for examining the dependence of spatial second-order structure on a continuous covariate. Methodology: A spatial point pattern of 300 trees was simulated in a 100 × 100 100×100 m region. Elevation was generated as a covariate with a linear southwest-northeast gradient (- 800 -800 to 1200 1200 m). Low-elevation points (n = 150 n=150) were artificially clustered into five clusters of radius 4 4 m, while high-elevation points (n = 150 n=150) were randomly dispersed. Ripley's K-function was computed for both elevation groups, and the test statistic T o b s T obs was defined as the sum of absolute differences between the two K-functions over various distances. A permutation test with 199 199 random label assignments was performed to obtain the distribution of the statistic under the null hypothesis. Findings: The observed test statistic was 50 , 137.81 50,137.81, while the mean under the null hypothesis was 4 , 013.42 4,013.42 (SD = 2 , 641.50 =2,641.50). All 199 199 permuted statistics were smaller than the observed value, yielding p = 0.005 p=0.005, which is statistically significant at the 95 % 95% confidence level. Conclusion: The null hypothesis is rejected. Elevation significantly affects tree clustering patterns: low elevations are associated with clustered (dense) patterns, while high elevations show dispersed patterns. The proposed permutation test provides a flexible, non-parametric tool for ecologists and spatial statisticians to investigate covariate-dependent second-order structures.

Keywords: Spatial point process,Second-order structure,Ripley's K-function,Permu tation test,Forest ecology,Elevation gradient

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Bayesian Estimation for the GIKw–Rayleigh Distribution under Various Loss Functions

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Abstract:
This document provides a comprehensive and self-contained treatment of Bayesian estimation for the four-parameter Generalized Inverse Kumaraswamy–Rayleigh (GIKw–RD) distribution. Starting from the probability density function, we derive the likelihood, choose independent Gamma priors, and ob tain the posterior distribution. Because the posterior lacks a closed form, we present two widely used computational approaches: Lindley's approximation and Markov Chain Monte Carlo (MCMC) with Metropolis-Hastings steps. Detailed formulas are given for the Bayes estimators under Squared Error Loss (SEL), Absolute Error Loss (AEL), LINEX Loss, and General Entropy Loss (GELF). All necessary derivatives, expansions, and algorithmic steps are explicitly written out. A simulation study illustrates the performance of the methods on two generated datasets. Keywords: Bayesian estimation, GIKw-Rayleigh distribution, Lindley approximation, MCMC, Loss functions, SEL, AEL, LINEX, GELF.
Keywords: GIKw- , ,SEL,AEL,LINEX,GELF

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Comparative Analysis of Bayesian Estimators for the MOAP-IL Distribution under Different Loss Functions

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Abstract:
The Marshall–Olkin Alpha Power Inverse Lindley (MOAP-IL) distribution is a flexible model for lifetime data with non-monotonic hazard rates. In this paper, we propose a Bayesian approach to jointly estimate the shape parameter α and the rate parameter γ. Because the posterior distribution is nonlinear and has no closed-form solution, we compute Bayesian estimates using MCMC with the Metropolis–Hastings algorithm. We study 13 loss functions in three groups: symmetric, asymmetric, and relative. Simulation results show that symmetric loss functions (such as SEL and Stein) usually give smaller MSE, while asymmetric loss functions (such as AREL and M-Linex) tend to produce more conservative estimates. This difference is important for risk-sensitive settings where overestimation and underestimation do not have the same cost. Convergence diagnostics, including trace and density plots, suggest stable estimation and good mixing, which supports the reliability of the proposed method.
Keywords: Bayesian inference, MOAP-IL distribution, Asymmetric loss functions, MCMC algorithm, and Markov chain convergence
Mathematics Subject Classification (2010): 62F15, 62F10.

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Evidential sets for the circular normal distribution

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Abstract:
Directional data arise in various applied fields, such as wind directions, daily event times, and bird flight directions. This paper addresses evidential intervals for directional data within the evidential inference framework. To this do, a sample coming from the circular normal distribution is assumed. Intervals for the population parameters are considered when the concentration parameter is either known or unknown. For large sample sizes, some approximations are also provided to enable fast computations with massive datasets. The performance of the proposed results is illustrated by analyzing a real dataset on the times of urban injury accidents.
Keywords: Likelihood Ratio, Circular and Directional Data, Evidential interval, Evidential sets.
Mathematics Subject Classification (2020): 62F25, 62H11, 62F15.

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Semiparametric Weibull Modeling for Constant Stress Accelerated Lifetime Tests using P-spline Neural Networks

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Abstract:
This study presents a semiparametric modeling approach for constant stress accelerated lifetime tests (CSALT) that utilizes P-spline and its artificial neural network (ANN) representation under a Type-I censoring scheme. In the proposed model, lifetimes are assumed to follow a Weibull distribution. The relationships between accelerated stresses and the characteristics of the lifetime distribution are modeled nonparametrically and additively using a B-spline approach. A penalty component is included in the loss function to regularize the model. To estimate the model parameters, a gradient-based optimization method, such as the Adam algorithm, is employed, while the smoothing parameters are estimated by minimizing the Akaike Information Criterion (AIC). The effectiveness of the proposed model is evaluated through a simulation study.
Keywords: Artificial neural networks, Constant stress accelerated lifetime tests, P-spline, Adam algorithm
Mathematics Subject Classification (2010): 62N05, 62G05, 62N01.

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A Robust Computational Framework for Time Series Clustering with Skewed Distributions

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Abstract:
This study develops a robust model-based clustering framework for time series by incorporating Laplace and Skew-Laplace distributions to address non-normality, skewness, and heavy-tailedness in real-world data. We assume that cluster observations follow a polynomial regression structure with a temporal Vandermonde design matrix. The model parameters are estimated using both Frequentist (via the EM algorithm) and Bayesian (via MCMC sampling) approaches. Simulation results indicate that while the Skew-Laplace model performs comparably to Normal and Laplace models under symmetric conditions, it significantly outperforms them when the data are skewed and heavy-tailed. In such scenarios, symmetric distributions tend to overestimate variance to compensate for their lack of flexibility, whereas the Skew-Laplace model provides a more robust and efficient fit. Furthermore, the Bayesian approach demonstrates superior performance over Frequentist methods, particularly in clusters with small sample sizes. These findings highlight the effectiveness of the Skew-Laplace model as a comprehensive and highly adaptable framework for complex time series analysis.
Keywords: Time series clustering, Bayesian inference, Robust estimation, Polynomial mixture models.
Mathematics Subject Classification (2010): 62M10, 62H30, 62F15.

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On a Novel Weighted Multivariate Normal Distribution Using Mahalanobis Distance

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Abstract:
The standard Multivariate Normal distribution is inherently unimodal and concentrates its probability mass at the mean, making it inadequate for modeling non-centralized or ring-shaped data. To address this limitation, we introduce the Mahalanobis-Weighted Multivariate Normal Distribution. By employing the squared Mahalanobis distance as a weighting function, the Mahalanobis-Weighted Multivariate Normal Distribution forces the central density to exactly zero, creating a topological "hole effect" without introducing any additional parameters. Compared to complex alternatives like Gaussian Mixture Models, the Mahalanobis-Weighted Multivariate Normal Distribution offers a strictly parsimonious and mathematically elegant solution. Simulation studies demonstrate its superior performance and computational efficiency in fitting crater-like data topologies, with broad applications in medical imaging, urban planning, and ecology.
Keywords: Weighted Distribution, Multivariate Normal Distribution, Mahalanobis Distance, Hole Effect
Mathematics Subject Classification (2010): 62H05, 60E05, 62E15.

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The Ising spin model on the square grid system based on Boltzmann distribution

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[2]**School of Mathematics, Statistics, and Computer Science, College of Science, University of Tehran, Tehran, Iran**

Abstract:
Many scientific disciplines have adopted the Ising model as a fundamental physical framework. Three specific configurations of this model are examined in this paper, with emphasis on the square $n \times n$ grid. For general Ising models built upon the Boltzmann stationary distribution, we show that the maximum likelihood estimator coincides with the method-of-moments estimator for the inverse temperature parameter β. Analytical solution of the resulting equation proves impossible; hence linear regression methods are employed to obtain these estimates. A general condition governing convexity of the Boltzmann probability entropy is also put forward.

Keywords: Entropy, Boltzmann distribution, maximum likelihood estimator, regression models, induced probability vector.

Mathematics Subject Classification (2010): 62B10, $62F10$, $62P35$, $62M10$.

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Time-Dependent Cumulative Past Fisher Information: Bounds, Orderings, and Mixture Representations

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Abstract:
This paper develops dynamic versions of cumulative past Fisher information measures for the past lifetime and inactivity time of a system. The proposed information functionals evolve over time and capture uncertainty from a retrospective viewpoint. We express them in terms of the reversed hazard rate and the mean inactivity time, derive sharp lower bounds using Cauchy–Schwarz and convexity arguments, and link them to reliability aging notions such as decreasing mean inactivity time and log-convexity. Stochastic orders based on the new dynamic information measure are introduced and characterized. Explicit formulas are obtained for the proportional reversed hazards model and for arithmetic mixture models, where the Fisher information is shown to equal four times a power mean of chi-square distances. Nonparametric estimators are also provided.
Keywords: Cumulative past entropy, Mean inactivity time, Mixture models, Reversed hazard rate, Stochastic orders.
Mathematics Subject Classification (2010): 62N05, 94A17, 62B10.

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A New Study for Bivariate Wavelet Density Estimation Under NSD Sample

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Abstract:

This paper focuses on the bivariate density estimation problem for negatively superadditive dependent sample. We construct and develop a new threshold wavelet methodology that defines a threshold based on the median of coefficients in each block. This approach offers advantages in terms of convergence rates and handling dependencies, making it suitable for various applications like hydrology data analysis. A simulation study is used to compare the performance of the new non-linear wavelet based estimator with the older estimator introduced previously in the literature.

Keywords: Bivariate density function, Negatively superadditive dependence, Non-parametric estimation, Wavelets.

Mathematics Subject Classification (2010): 62G07, 62N02.

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Asymptotic Power Analysis for Testing Points of Impact under Brownian Motion Predictors

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Abstract:
Functional linear regression models with points of impact provide an important framework for identifying localized effects of functional predictors. In this paper, the asymptotic behavior of the test statistic for points of impact, proposed by **?**, is investigated under Brownian motion predictors. Using the explicit spectral decomposition of Brownian motion, simplified expressions for the covariance structure and the asymptotic power function are derived. Under local alternatives, the limiting distribution of the test statistic is shown to converge to a noncentral chi-square distribution with an explicit noncentrality parameter. Simulation studies demonstrate satisfactory finite-sample performance and illustrate the effect of the impact location on the asymptotic power of the proposed test.
Keywords: Functional data analysis, Functional linear regression, Points of impact, Brownian motion, Asymptotic power.

Mathematics Subject Classification (2010): 62G35, 62J05, 60G15.

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Jackknife Ridge Estimation in Linear Mixed Models with Measurement Error

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Abstract:

This study investigates the problem of bias in linear mixed models (LMMs) when ridge estimation is applied in the presence of measurement errors in fixed-effect variables. First, the ridge estimator for LMMs is described, and then a new estimator, called the jackknife ridge estimator (JRE), is proposed. The performance of the proposed estimator is compared with the conventional ridge estimator, demonstrating improvements in terms of bias and mean squared error. In addition, the asymptotic properties of both estimators are derived. Finally, simulation studies and a numerical example are presented to evaluate the efficiency of the proposed estimator.

Keywords: Jackknife ridge; Linear mixed models; Measurement error; Bias reduction; Asymptotic properties

Mathematics Subject Classification (2010): 99X99, 99X99, 99X99.

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Joint Modeling of Zero-Inflated Longitudinal Count Data and Survival Outcomes with Cure Fraction

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Abstract:

Background: Longitudinal data with excess zeros and survival data with a cured fraction are common in medical research, often exhibiting interdependence that complicates analysis. Joint modeling of these data types can address this interdependence, potentially improving estimation accuracy over independent models. This study introduces a joint model that integrates a zero-inflated count model for the longitudinal process with a mixture cure model for the survival process and investigates the performance of joint models compared to independent models under varying conditions of zero-inflation, cure rates, and sample sizes.

Methods: We analyzed 500 datasets with sample sizes of 500 and 800 as part of a simulation study that included 32 scenarios. Zero-Inflated Poisson (ZIP) and Zero-Inflated Negative Binomial (ZINB) distributions were used to generate longitudinal count data, with zero-inflation rates of 43%-50% and 69%-75%, respectively. A mixture cure model was used to model survival data, which included cure rates of 47%-50% and 59%-66%. Joint models, fitted using Bayesian techniques with JAGS in R, connected longitudinal and survival processes through shared random effects. By comparing the bias in parameter estimates between joint and independent models, the performance of the models was assessed.

Results: Joint models consistently outperformed independent models, showing lower bias across most parameters. Joint modeling of ZINB longitudinal count data and survival data with a cure fraction (JZINBC model) exhibited less bias than joint modeling of ZIP longitudinal count data and survival data with a cure fraction (JZIPC model) in high zero-inflation settings due to better handling of overdispersion, while JZIPC model performed better with lower zero-inflation (43%-50%). Larger sample sizes (800) reduced bias compared to smaller samples (500). Lower cure rates (47% - 50%) generally improved estimation accuracy, especially in joint models.

Conclusion: Joint modeling of zero-inflated longitudinal count data and survival data with a cure fraction (JZIC model) provides more accurate parameter estimates than independent models, particularly in complex scenarios with high zero-inflation and cure rates. These findings highlight the importance of joint modeling in medical research involving interdependent longitudinal and survival outcomes.
Keywords: Zero-inflated, longitudinal count data, mixture cure model, joint model.
Mathematics Subject Classification (2010): 99X99, 99X99, 99X99.

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Mixed-Effects Hurdle Trees for Longitudinal Zero-Inflated Count Data

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Abstract:
Longitudinal count data with excess zeros are common in many applied fields, yet flexible tree-based methods for such data remain scarce. This paper introduces the Penalized Quasi-Likelihood Hurdle Tree (PHT), a novel algorithm that combines regression trees with mixed-effects models to capture nonlinear fixed effects and subject specific correlations in zero-inflated longitudinal counts. The PHT employs a penalized quasi-likelihood approximation, alternating between estimating random effects and updating tree-based fixed effects via weighted pseudo-responses. Simulation studies demonstrate that PHT outperforms standard regression trees, Poisson GLMMs, and hurdle GLMMs in terms of predictive accuracy. An application to a salamander abundance dataset further confirms the practical utility of PHT, revealing key ecological drivers while achieving the lowest out-of-sample prediction error.
Keywords: Longitudinal data, Zero-inflated count data, Hurdle model, Mixed-effects model, Regression tree, Penalized quasi-likelihood.
Mathematics Subject Classification (2010): 99X99, 99X99, 99X99.

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Parameters Estimation of the Lomax-Lindley Distribution Utilizing Record Data

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Abstract:
This paper is devoted to the problem of parameters estimation based on record values from Lomax-Lindley distribution. The estimation of parameters are obtained by using the maximum likelihood method and Bayesian method under squared error and linear-exponential loss functions. A Monte Carlo simulation study is conducted to investigate and compare the performance of different types of estimators presented in this paper. Based on our simulation outcomes, it is observed that the Bayesian estimators perform better than the MLEs in the estimation of the unknown parameters.
Keywords: Lomax-Lindley distribution, Maximum likelihood estimation, Bayesian estimation, and Record values.
Mathematics Subject Classification (2010): 62F15, 65C05.

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Bivariate Quantile Regression Analysis for Longitudinal Cardiovascular Risk Factors

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Abstract:

Modeling the joint evolution of correlated cardiovascular risk factors across their full distribution remains a statistical challenge, as traditional mean-based longitudinal methods fail to capture extreme-dependent associations and heterogeneous covariate effects. We present a bivariate quantile regression framework for longitudinal data based on the generalized Johnson distribution and the Rosenblatt transformation. The method enables simultaneous modeling of two correlated outcomes at arbitrary quantile levels while preserving interpretability and automatically avoiding quantile crossing. A computationally efficient maximum likelihood estimator is developed with consistency and asymptotic normality guarantees. A comprehensive simulation study demonstrates that the proposed quantile regression model consistently outperforms all competing methods across all evaluation metrics.

Keywords: Bivariate analysis, Correlated outcomes, Generalized Johnson distribution, Longitudinal data, Rosenblatt transformation.

Mathematics Subject Classification (2010): 99X99, 99X99, 99X99.

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European option valuation with modified Heston model under stochastic market liquidity

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Abstract:

Comprehensive modeling of stock prices plays a critical role in financial derivatives valuation. Although, the classic Heston model captures the stochastic volatility, it struggles to replicate the term structure of implied volatility and assumes a perfectly liquid market. To address these inconsistencies, we introduce a Heston model by incorporating independent Ornstein–Uhlenbeck processes for both the long-term mean of volatility and stochastic market liquidity. Moreover, we derive an analytical European option pricing formula and validate the model using real market data from leading companies. We employ the root mean square error to assess the superiority of the introduced model against three benchmark models in replicating European option prices and implied volatility.

Keywords: European option pricing, Heston model, Stochastic liquidity, Stochastic volatility

Mathematics Subject Classification (2020): 91G20, 91G30, 60J76.

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Stress–Strength Reliability with Clayton Copula and Generalized Rayleigh Marginals

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Abstract:
This study estimates stress-strength reliability when the stress and strength variables are dependent. The dependence is modeled by the Clayton copula, which captures lower-tail association, and the marginals follow the generalized Rayleigh distribution. A unified framework is developed that includes maximum likelihood estimation, bootstrap confidence intervals, and Bayesian estimation under different loss functions using a Metropolis-within-Gibbs sampler. A Monte Carlo simulation evaluates the performance of the estimators, and a real data example shows the practical use of the model. The findings indicate that ignoring dependence can lead to biased reliability estimates.
Keywords: Generalized Rayleigh distribution, Clayton copula, stress-strength reliability, Bayesian inference.
Mathematics Subject Classification (2010): 62N05, 62F15, 62H05.

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Moving Extreme Ranked Set Sampling for Imbalanced Binary Classification: A Logistic Regression Perspective

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Abstract:
Logistic regression (LR) is widely used for binary classification, yet its performance is often compromised by class imbalance and inefficient sampling. Moving extreme ranked set sampling (MERSS) offers a potential solution by utilizing auxiliary information to target extreme observations where rare events reside, but its impact on LR classification has not been systematically evaluated. This study compares SRS and MERSS for LR classification under imbalanced conditions ($r = 0.2, 0.3, 0.4$), varying sample sizes ($n = 120, 210, 300$), correlations ($\rho = 0.3, 0.5, 0.7$), and set sizes ($k = 3, 5, 10$). Results demonstrate that MERSS consistently outperforms SRS, particularly for minority class identification. The largest gains were observed under the most severe imbalance ($r = 0.2$), where MERSS improved Precision by up to 15% and Minor-F1 by up to 29% compared to SRS, with no additional computational cost. These findings establish MERSS as a highly efficient sampling strategy for LR classification in imbalanced data, improving rare event prediction without increasing resource expenditure.
Keywords: Logistic regression, Moving extreme ranked set sampling (MERSS), Imbalanced classification
Mathematics Subject Classification (2010): 62D05, 62J12, 62P10.

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Comparative Evaluation of Synthetic Medical Data Generation Methods in Pediatric Osteopenia

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Abstract:
Medical datasets, often suffer from limited sample sizes. Synthetic data generation may support data augmentation, privacy-preserving sharing, and methodological validation. This study compared six synthetic data generation strategies using a pediatric osteopenia dataset ($n = 71$) from children with type 1 diabetes mellitus, including conditional and non-conditional Bootstrap, Multivariate Normal (MVN), and Gaussian Copula methods. Synthetic datasets of 500 samples were evaluated using utility (TSTR ROC analysis), fidelity (Kolmogorov–Smirnov testing and correlation preservation), and privacy (Nearest Neighbor Distance Ratio; NNDR) assessments. The real-data model achieved an AUC of 0.796. Conditional Bootstrap ($AUC = 0.786$), conditional MVN ($AUC = 0.776$), and conditional Copula ($AUC = 0.776$) preserved predictive performance well, whereas the non-conditional Copula approach performed poorly ($AUC = 0.224$, $p = 0.011$). Bootstrap and Copula methods showed strong distributional similarity, while conditional MVN demonstrated the best correlation preservation. Privacy analysis indicated high disclosure risk for Bootstrap methods, whereas MVN and Copula approaches provided substantially better privacy protection. Overall, conditional MVN provided the best balance between utility, fidelity, and privacy preservation in this low-sample clinical setting.

Keywords: Synthetic data, Multivariate normal, Gaussian copula, Bootstrap, Pediatric osteopenia
Mathematics Subject Classification (2010): 62H12, 62P10, 68T07.

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Likelihood-Based Evidential Comparison of Classical Goodness-of-Fit Tests

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Abstract:

The Law of Likelihood establishes that the strength of statistical evidence favoring one hypothesis over another is represented by their likelihood ratio. Within the framework of evidential statistics, this study compares the performance of several classical goodness-of-fit tests—including the Anderson–Darling, Kolmogorov–Smirnov, Cramér–von Mises, Watson, and Likelihood Ratio Test—based on their ability to yield reliable and interpretable evidence. Simulation results across different sample sizes quantify the probabilities of weak and misleading evidence under both null and alternative models, offering new insights into the evidential performance of these tests.

Keywords: Evidential statistics, Goodness-of-fit tests, Law of Likelihood, Misleading evidence, Weak evidence.

Mathematics Subject Classification (2010): 62F25, 62G15.

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Stein Estimators in Right-Censored Zero-inflated Bell Models

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Abstract:
In the current paper, we propose Stein and positive Stein estimators to improve the efficiency of parameters estimation in the zero-inflated Bell models with right-censored data, assuming that some predictor variables are non-significant. A Monte Carlo simulation study is conducted under various settings, including different censoring constants, and non-significant predictors, to compare the performance of our estimators with the unrestricted estimator. The results demonstrate the superiority of our approach.
Keywords: Right-censored data, Stein estimator, Positive Stein estimator, Zero-inflated Bell model.
Mathematics Subject Classification (2010): 62J07, 62N01.

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