MMR
2025

13th Internacional Conference On

Mathematical Methods In Reliability

Plenary Talks

Speaker: Maria Kateri
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Affiliation: RWTH Aachen University (Germany)
Title: Step-Stress Accelerated Life Testing Models: Statistical Inference and Optimal Experimental Design

Abstract: Accelerated life testing (ALT) is widely used in reliability analysis across a range of fields, from material sciences and quality control to biomedical sciences and ecology statistics. Step-stress models form an essential part of ALT. In a step-stress ALT (SSALT) model, test units are subjected to gradually increasing stress levels at intermediate time points throughout the experiment. Statistical inference is then developed to estimate parameters such as the mean lifetime under each tested stress level. Parameter estimates under normal operating conditions can be derived by using a link function that connects the stress levels to the corresponding parameter of the assumed lifetime distribution. Respective statistical models are specified according to the assumptions made regarding the time points of stress level change, the experiment's termination point, the underlying lifetime distributions, the type of censoring (usually present), and the way of monitoring failures.

We explore SSALT models and their adaptability in various experimental setups. Our focus is on a model that employs a general scale family of distributions, offering flexibility and leading to explicit expressions for the maximum likelihood estimators of the scale parameters in the underlying lifetime distributions. The approach is demonstrated for Type-I censored experiments, considering both continuous and interval monitoring of the test units. We address maximum likelihood, maximum product of spacings, as well as Bayesian estimation. Additionally, we discuss optimal experimental design for SSALT experiments. Finally, we consider SSALT modeling in heterogeneous populations, where test items are grouped according to their aging behavior. In such cases, heterogeneity is captured using a mixture model approach.

Speaker: Enrique Lopez Droguett
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Title: Quantum Computing for Risk and Reliability: Outlook & Opportunities

Abstract: Industry 4.0, combined with the Internet of Things (IoT), has ushered in the requirements of risk, reliability, and maintainability systems to predict physical asset's performance and aid in integrity management. State of the art monitoring systems now generate large amounts of multidimensional data. Moreover, customers are no longer requiring that their new asset investment be highly reliable; instead, they are requiring that their assets possess the capability to perform fault diagnostics and prognostics and provide alerts when components need to be intervened. With this new Big Data at the engineer's fingertips, more sophisticated methodologies to handle this data have been developed and expanded within the risk and reliability (R&R) field. Indeed, in the past decade, the availability of powerful computers and special-purpose information processors have led to the development and application of machine and deep learning models for the assessment of R&R of complex engineering systems (CES) that can identify multifaceted and subtle degradation patterns in monitoring data.

In recent years, a new computing paradigm has gained momentum: quantum computing, which encompasses the use of quantum mechanical phenomena to perform computations. The power and flexibility of a quantum computer comes from the use of qubits that have the ability to be in a superposition state, or multiple states at once, and share entanglement with each other. By leveraging on these properties, quantum computers can perform operations that are difficult to achieve at scale in classical digital computers. This opens the door to new exciting opportunities for the design and performance assessment of complex engineering systems in general, and for the development of new quantum methods for R&R that might be able to recognize intricate interdependent scenarios and components as well as multilayered degradation patterns in CES from multidimensional monitoring data that classical machine learning approaches cannot.

In this lecture, we discuss the main concepts underpinning quantum computing and its advantages, disadvantages, and potential impact on the risk and reliability assessment of CES. We present state-of-the-art quantum optimization, quantum inference, and machine learning algorithms for developing predictive solutions for risk and reliability assessment of complex engineering systems. We then examine potential opportunities, limitations, and challenges for the future development and deployment of quantum computing based risk and reliability solutions for complex engineering systems.

Speaker: Luis E. Nieto-Barajas
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Title: Markov Processes in Survival Analysis

Abstract: In this talk we present some discrete and continuous Markov processes that have shown to be useful in survival analysis and other biostatistics applications. Both discrete and continuous time processes are used to define Bayesian nonparametric prior distributions. The discrete time processes are constructed via latent variables in a hierarchical fashion, whereas the continuous time processes are based on Lévy increasing additive processes. To avoid discreteness of the implied random distributions, these latter processes are further used as mixing measures of the parameters in a particular kernel, which lead to the so-called Lévy-driven processes. We include univariate and multivariate settings, regression models and cure rate models.

Speaker: Bruno Tuffin
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Affiliation: INRIA Rennes (France)
Title: Importance Sampling for the Rare Event Simulation of Reliability Models

Abstract: Monte Carlo simulation methods are often the only tools to get an estimation of performance measures of complex systems. When dealing with the specific class of reliability, we typically require the estimation of probability of order 10^{-9} or even less. It is for example the case of one considers the probability of a failure of nuclear plant, the probability of ruin of an insurance company, the saturation probability in telecommunication. In this case, the crude Monte simulation method, which simply means simulating the system model as many times as possible to obtain the rare event a sufficient number of times is computationally inefficient. Specific methods have been developed in the literature for this rare context, mainly grouped into two classes, importance sampling and importance splitting (also called subset simulation).

During this talk, we are going to review the most efficient application of importance sampling on two types of reliability models: static and dynamic ones. Static models mean that we do not have a stochastic model evolving with time; the system typically has a huge space of states decomposed into two classes, where the system works and where the systems not operational. We often then look at the probability that the systems is down. Dynamic reliability models have components subject to failures and repairs, potentially grouped; we are here interested in the probability of failure of the whole system at a given time, over an interval of time, or the mean time to failure. In each case, we will describe how importance sampling can be applied and discuss the robustness of the estimators with respect to some rarity parameter. We will also discuss the determination of quantile of time to failure, of particular importance for warranty setup for example.

Invited Talks

Speaker: Yi-Shian Dong
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Affiliation: National Chengchi University (Taiwan)
Title: Acceleration Invariance Principle for Hougaard Processes in Degradation Analysis

Abstract: Accelerated degradation tests (ADTs) are widely used to assess lifetime information under normal use conditions for highly reliable products. For the accelerated tests, two basic assumptions are that changing stress levels does not affect the underlying distribution family and that there is stochastic ordering for the life distributions at different stress levels. The acceleration invariance (AI) principle for ADTs is proposed to study these fundamental assumptions. Using the AI principle, a theoretical connection between the model parameters and the accelerating variables is developed for Hougaard processes. This concept can be extended to heterogeneous gamma and inverse Gaussian processes. Simulation studies are presented to support the applicability and flexibility of the Hougaard process using the AI principle for ADTs. A real data analysis using the derived relationship is used to validate the AI principle for accelerated degradation analysis.

Speaker: Pierre Dersin
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Title: Degradation Kinetics and Predictive maintenance

Abstract: It is important, when monitoring assets, to assess and predict degradations - the progressive loss of performance over time, before they result in failures, to organize predictive maintenance. Examples of industrial systems where this is relevant include crack growth propagation, rail track defect propagation, degradation of pipelines due to corrosion, degradation of batteries, to name but a few. To that end, time transformations are introduced, which convert any time-to-failure distribution into a distribution of the Hall-Wellner family, where mean residual life is a linear function of time and confidence bounds on RUL are expressed explicitly. The methodology is illustrated on frequently encountered distributions, such as Weibull and Gamma ; as well as on systems including active redundancies. If degradations' time evolution can be described by a stochastic process, a family of time transformations, indexed by the degradation level, can be defined . This is illustrated on some examples, for instance described by a Wiener process with drift. Based on a confidence interval for the RUL, predictive maintenance policies with pre-defined bounded failure risk can be scheduled. When conditions of use change dynamically, the time transformation and the maintenance schedule can be updated accordingly, reflecting the evolving degradation dynamics. Identification of the appropriate time transformation from field data is addressed next. For instance a frequency-domain approach, based on the moment-generating function of the time to failure, is described. It can be used in conjunction with neural networks in order to identify the time transformation.

Speaker: Francisca Molina
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Affiliation: Universidad Adolfo Ibáñez (Chile)
Title: Building Survival Trees Combining Weighted Log-Rank Statistics

Abstract: Survival random forests (SRF) are a widely used extension of random forests designed to handle right-censored survival data. Traditionally, SRFs employ the log-rank test as a splitting criterion, which relies on the proportional hazards assumption. However, this assumption often fails in real-world scenarios where hazard functions may cross or vary over time. To address this limitation, we propose a novel SRF framework that incorporates a combination of weighted log-rank tests as the splitting rule. These weighted tests are known to be more powerful in non-proportional hazard settings, each emphasizing different aspects of the hazard function. By combining them, we aim to construct a more flexible and robust splitting criterion that adapts to diverse data structures without prior knowledge of the underlying hazard dynamics. Our approach is designed to maintain computational efficiency while improving predictive performance across a broad range of survival scenarios. This project will focus on the implementation, evaluation, and comparison of the proposed method against classical SRF models using both simulated and real datasets.

Speaker: Laurent Doyen
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Affiliation: Université Grenoble Alpes (France)
Title: General framework for univariate degradation with imperfect maintenance: modelling, inference and application to real data

Abstract: Degradation modelling and maintenance of industrial systems have gained increasing interest due to their potential to analyze asset deterioration leading not necessarily to observed failures. In this work, the system degradation of a new system in the absence of maintenance is supposed to follow a Wiener process. In order to contain the degradation, different types of maintenance actions are performed. All the maintenance effects are supposed to follow an ARD infinite model with different maintenance efficiency parameters r depending on the maintenance type. That means that the effect of maintenance is to reduce the degradation level of a 100r% of its value before maintenance. The first contribution of this work is to derive a closed-form expression of the degradation level of the maintained system and to study the probability properties of its distribution. The second contribution is to propose a likelihood inference method based on observations of degradation levels of the maintained system. The considered scheme is completely general in the sense that it can take into account observations done before, after or between maintenance actions. However, none of these different types of observation is imposed. For example, between two determined maintenance actions, there can be no observations at all, and on another interval between maintenances there can be only observations between maintenances or between and before maintenances. All configurations are conceivable and mixable. Finaly, the proposed framework is applied to analyze a real data set issued from EDF, the main French power utility.

Speaker: Emmanuel Remy
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Affiliation: Performance, Risque Industriel, Surveillance pour la Maintenance et l'Exploitation (France)
Title: How to handle a large number of preventive replacements?

Abstract: Due to their flexibility and their role in securing the electrical grid against the intermittent nature of new renewable energies, the French hydroelectric fleet plays an essential role that will intensify in the future. By starting and stopping more frequently to fill energy gaps in the grid, hydraulic power transformers may wear out more significantly than before. Quantifying their lifetime based on their usage profile and optimizing their operation and maintenance is therefore a major challenge for EDF. A technical difficulty lies in the fact that the experience feedback of power transformers consists of a significant number of preventive replacements. Traditionally, these replacements can be treated as right censored data. However, their high proportion in the data can lead to an estimation of the survival function that is not representative of the true reliability of the equipment. The purpose of this work is to present, implement and compare the results of different approaches to circumvent this inherent limitation in the experience feedback data of hydraulic power transformers.

Speaker: Brahim Mebrek
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Affiliation: Performance, Risque Industriel, Surveillance pour la Maintenance et l'Exploitation (France)
Title: Integrating health status information in reliability análisis

Abstract: Hydroelectric power plants play a crucial role in the French energy mix. Their longevity has allowed for the accumulation of decades of expertise and valuable operational data. Their flexibility, defined as their ability to respond quickly to electricity demand fluctuations, as well as their compatibility with intermittent renewable energies, reinforce their role in the future energy landscape. However, the evolution of electrical grids introduces new challenges that accelerate the wear of components, particularly power transformers.

Thus, quantifying the lifetime of these assets and optimizing operation and maintenance strategies have become key priorities for industrial operators such as EDF. To construct realistic lifetime models, it is essential to integrate a wide range of quality data, although these cannot be treated uniformly. The integration of failure data and material characteristics, such as the technology and the manufacturer, is well mastered. In contrast, the consideration of punctual indicators, such as equipment health status, remains complex. Health indicators for power transformers are developed by aggregating criteria from technical diagnostics performed by experts in these systems. This paper presents an innovative approach to integrate these health indicators to refine the reliability estimates in statistical models.

Speaker: Sheng-Tsaing Tseng
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Affiliation: National Tsing Hua University (Taiwan)
Title: Lifetime Inference of Highly-Reliable with Recurrent-Event Products and It's Applications to the Lifetime Prediction of Rechargeable Batteries

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Abstract: Conducting a cost-efficient lifetime-testing plan to timely assess lifetime information of reusable products is a challenging task in the industry. Motivated by a case study of rechargeable batteries, this work introduces a multi-run k-level step-stress experiment (in which different stresses are repeated in a cycle fashion) to collect the degradation data of lithium-ion batteries. We formulate the battery capacity over recharge cycles as a counting process and then adopt a trend renewal process (TRP) to characterize the degradation patterns of capacity varying with the stress level of the accelerated factor. By assuming a Markov property hold in our counting process, the degradation data observed in a multi-run k-level step-stress TRP model can be equivalently converted to their counterparts in k constant-stress TRP models. Based on this connection, we estimate the parameter using maximum likelihood and infer lithium-ion batteries' end-of-performance (EOP) at normal-use conditions with uncertainty quantification.

Speaker: Yufen Huang
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Affiliation: National Cheng Kung University (Taiwan)
Title: Local Influence on Wiener Process in Degradation Analysis

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Abstract: Stochastic process models (SPM) have been widely used in the investigation of random phenomena evolving in time or space. Three commonly used stochastic models in the degradation analysis are Wiener process, gamma process and inverse Gaussian process. In this talk, we will restrict our discussion on Wiener process model. During the degradation model fitting process, degradation paths that are suspicious can greatly influence the results on modeling and forecasting. Consequently, detection of such influential paths becomes an essential task. To our knowledge, a study in the influence analysis on Wiener process model has not been explored in the literature. Therefore, this becomes the focus of this talk. Perturbation theory provides a useful tool to assess the influence of abnormal paths. One useful tool for studying the influence analysis in statistical models is Cook's (1986) local influence. We first revisit the local influence in Cook (1986) and Wiener process model, then we develop local influence on the degradation paths of the Wiener process model as tools for influential paths detection. Finally, simulation studies and real data examples are provided for illustration.

Speaker: Marco Capaldo
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Title: On ROC curve distortion functions

Abstract: Distortion functions were introduced by Yaari in the theory of choice under risk, aiming to perform a ``distortion" on the initial risk distribution. Nowadays distorted distributions are employed in several fields, such as Order Statistics, Reliability Theory and Survival Analysis, to name a few. In this talk, new distortion functions based on the well-known Receiver Operating Characteristic (ROC) curve are introduced and studied in detail. Some of them are related with the concept of partial area under the ROC curve through recent univariate skewed models. By using the interpretation of such distortions as cumulative distribution functions of suitable relative random variables, we characterize various stochastic orders and aging classes. Connections with equilibrium distribution, Lorenz curve and Gini's index are provided too. A real data application of the distortion-based results allows us to evaluate the performance of some Machine Learning classifiers by using semiparametric estimations of the ROC.

Speaker: Hung-Ping Tung
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Title: Optimal designs for gamma degradation tests

Abstract: As a product approaches launch, assessing product lifetime becomes a critical issue for manufacturers. Degradation tests, which are widely used in industry, are one method for this evaluation. Among various degradation models, gamma processes are suitable for modeling degradation data with monotonic properties. To efficiently design a gamma degradation test, several studies have explored optimal design under cost constraints, including considerations for the number of test units, measurement times, number of measurements, and testing termination time. However, because of practical convenience, most of the existing literature focuses on designs with equal measurement intervals and provides limited discussion on measurement interval planning. In this study, we present optimal designs for two scenarios: the equal measurement time plan and the optimal measurement time plan. We propose the properties of approximate optimal designs and introduce two algorithms to determine the integer optimal design for practical implementation.

Speaker: I-Chen Lee
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Title: Optimal Sample Size Allocation for Accelerated Degradation Tests With Different Measurement Time Based on Gamma Process

Abstract: The accelerated degradation test (ADT) is widely used to assess the lifetime information for highly reliable products. To obtain the failure information more efficiently, how to design an efficient ADT plan is a critical task for real applications. Assume that the degradation path follows gamma degradation models, including the fixed effect degradation models and random effect degradation models. In this study, we mainly focus on the determination of sample size allocation, and we allow the lengths between two consecutive measurements can be different for different stress levels. The theoretical and numerical solutions are provided, and the results demonstrate that the different lengths of measurement intervals for different stress levels indeed affect the optimal sample allocation. Through simulation studies, we validate that the proposed strategy is exactly an optimal design and is better than the existing strategies based on the gamma process.

Speaker: Javiera Barrera
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Title: Power grid reliability under the effects of forest fires

Abstract: The use of electric energy is increasing and will continue to do so shortly. In a society increasingly seeking carbon neutrality, the electrification of industrial processes, automobiles, and heating systems is key. To keep these energy networks operating correctly, the possible effects on them of various natural disasters, including forest fires, which, in Chile alone, devastated more than 420,000 hectares in the summer of 2023, must be taken into account. This work proposes a method to design an extension of the electrical transmission network that ensures a greater resilience of this network when affected by a forest fire. We simulated wildfire scenarios and the corresponding components failures, analyzed the network response, and chose to add those elements that minimize the associated operating, generation, and social costs.

Speaker: Jorge Navarro
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Title: Preservation of aging classes under the formation of coherent systems

Abstract: We show that some distributions play a crucial role in the aging classes closure under the creation of semi-coherent (or mixed) systems with identically distributed components. In this way, if the class is inherited for that key distributions, then so is for the remaining distributions included this class. In the most important aging classes, the key distribution is the exponential one, which plays a central role in this context since it represents units without aging (with the lack of memory property). In other classes the key distributions are the uniform and Pareto models.These distributions lead to mathematical properties that may be useful to decide if an aging class is inherited by a specic system. We consider both the cases of systems with independent and dependent components.

Speaker: Francesco Buono
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Title: Quantile regression prediction of classical and generalized order statistics

Abstract: The problem of predicting future order statistics in a sample from early observed values (type II censored data) is addressed by using quantile regression techniques. Both the case of independent and dependent lifetimes are analyzed assuming identically distributed random variables. Then, quantile regression predictions are considered for generalized order statistics extending also the results about record values. In particular, the prediction of the s-th generalized order statistic given the generalized r-th order statistic, with r less than s, is addressed. In order to derive the results, some (univariate and bivariate) distortion representations of classical and generalized order statistics are established.

Speaker: Paulo H. Ferreira
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Title: Reliability analysis of multiple repairable systems under imperfect repair and unobserved heterogeneity

Abstract: Imperfect repairs (IRs) are widely applicable in reliability engineering since most equipment is not completely replaced after failure. In this sense, it is necessary to develop methodologies that can describe failure processes and predict the reliability of systems under this type of repair. One of the challenges in this context is to establish reliability models for multiple repairable systems considering unobserved heterogeneity associated with systems failure times and their failure intensity after performing IRs.

Thus, in this work, frailty models are proposed to identify unobserved heterogeneity in these failure processes. In this context, we consider the arithmetic reduction of age (ARA) and arithmetic reduction of intensity (ARI) classes of IR models, with constant repair efficiency and a power-law process distribution to model failure times and a univariate Gamma distributed frailty by all systems failure times. Classical inferential methods are used to estimate the parameters and reliability predictors of systems under IRs. An extensive simulation study is carried out under different scenarios to investigate the suitability of the models and the asymptotic consistency and efficiency properties of the maximum likelihood estimators. Finally, we illustrate the practical relevance of the proposed models on two real data sets.

Speaker: Guido Lagos
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Title: Simple repair policies for general coherent systems with simultaneous failures

Abstract: In this work, we study repair policies for reliability networks that are subject to simultaneous failures of its components. Indeed, we assume that "shocks" arrive in a continuous-time Markovian fashion, each shock hits a subset of the components, and once a component is hit it stops working. Depending on the configuration of working and failed components, the network can be either working or non- working. Furthermore, a failed component can be repaired at a component-repair cost, and also the whole network can be repaired once it fails, at a (higher) network-repair cost. Hence, a trade-off arises between saving the component-repair cost by letting them fail, and saving the network-repair cost by repairing components so the network has less chance of failing. We study several repair policies in this setting. Indeed, we consider a family of simple but interpretable repair policies where all failed components are repaired when r or more components have failed, and derive exact expressions for the expected network failure time and for the long-term average cost. Then we consider more involved policies derived using Markov Decision Processes, and compare their performance to the simple repair policies. We study conditions under which one policy is better than the other.

Speaker: Su-Fen Yang
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Title: The Exact and asymptotic Ratio of Proportions Control Charts

Abstract: This article outlines the development of two control charts for monitoring the ratio of two binomial proportions independent populations. Assuming an in-control process, we treat the two proportions and the covariance between the populations as known and constant. We propose both exact and asymptotic control charts to monitor the ratio of these proportions. To construct the asymptotic control chart, we use the distribution of the logarithmic ratio of two sample proportions. We then transform the in-control ratio of proportions into a linear combination of the two dependent proportions. This allows us to develop an unbiased estimator of the linear combination, leading to the construction of the exact ratio of proportions control chart. We also examine the properties and detection performance of both control charts through numerical analysis. The results demonstrate that the proposed exact ratio control chart provides accurate process monitoring and quick detection of out-of-control conditions, even for varying sample sizes.

Speaker: Vasiliy Krivtsov
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Affiliation: Ford Motor Company & University of Maryland (United States)
Title: Useful Generalization of Arithmetic and Geometric Age Reduction Models in Recurrent Events Analysis

Abstract: A variety of models is available for repairable systems, including those requiring general repairs. Most popular are the Kijima models (reflecting the generalized renewal process of recurrent failures) and the Lam model (reflecting the geometric process). The Kijima models relating the system's real and virtual ages can be thought of as the time shift transformation (i.e., arithmetic age reduction), whereas The Lam model – as the time scale transformation (i.e., geometric age reduction). In this paper, a new model is proposed that combines these two fundamental transformations within a new probabilistic formulation. Besides the probabilistic aspect of the model, the maximum likelihood estimation of model parameters is discussed, and its performance is illustrated through several numerical examples using automotive warranty data.

Contributed Talks

Speaker: Zhe Su
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Title: A geometric-exponential mixture model for lifetime data

Abstract: In reliability studies, lifetime data are commonly observed continuously over time, although the observations may also be recorded discretely in case of periodic inspections. We focus on joint statistical inference based on independent experiments with either continuously or discretely observed lifetime data. When items with exponentially distributed lifetimes are only inspected at non-negative integer time points, the observations correspond to realizations of a discretized version of the lifetime distribution, and thus to a geometric distribution with the same distribution parameter involved. We propose and examine a geometric-exponential mixture (GEM) model for the situation, where continuously recorded lifetimes as observations from an exponential distribution as well as lifetimes from identically distributed items monitored at integer time points are available. The GEM model leads to a regular exponential family such that well known tools and statistical methods can be applied. From a minimal canonical representation of the exponential family associated with the GEM model, we obtain the cumulant function and the mean value function; see, e.g., Bedbur and Kamps (2021). We then discuss existence and uniqueness of the maximum likelihood estimators as well as uniformly minimum variance unbiased estimators for the distribution and the mixture parameters. Moreover, we develop uniformly most powerful (unbiased) tests and uniformly most accurate (unbiased) confidence intervals and provide some examples.

Speaker: Andrés Catalán
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Title: Advancing individual log anomaly detection in distributed systems: A bidirectional encoder representation from transformers approach integrating sentiment analysis and explainability

Abstract: Logs are essential for monitoring the operational status of highly complex and distributed systems. Due to the large volume of logs generated by these infrastructures, deciphering this extensive data poses a significant challenge even for experienced operators. These logs contain textual descriptions detailing the system's functioning in natural language, which intelligent models can leverage to detect anomalies through sentiment analysis. This technique identifies the polarity (positive or negative) within the text, which can be directly linked to normal or abnormal behavior. In this context, we propose an architecture based on Bidirectional Encoder Representations from Transformers with In-Task Pre-Training and fine-tuning (BERT-ITPT-FiT) for detecting log anomalies. This approach is particularly notable for its ability to enhance explainability through SHapley Additive exPlanations (SHAP) values, highlighting each word's contribution to the classification process. Our investigation revealed that while strong performance is critical, it alone does not guarantee a reliable anomaly detection model; factors such as scalability, semantic context, and interpretability are equally important. Experimental results on publicly available system log datasets demonstrate that our method addresses the limitations of existing techniques, achieving F1 scores of 99.96% on in-domain datasets (used for both training and testing) and 96.81% on out-of-domain datasets (used exclusively for testing) showcasing robust transfer learning capabilities.

Speaker: Ignacio Riego
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Title: An Automated Maintenance Planning Solution with Personalized Check Creation

Abstract: Efficient aircraft maintenance planning is critical for ensuring safety, minimizing costs, and maximizing fleet availability in the competitive airline industry. Creating long-term maintenance plans for medium- to large-sized fleets is particularly challenging due to the sheer scale of the problem, which involves thousands of tasks, interdependent constraints, and distributed resources. In this work, we present an automated solution based on three integrated optimization models that interact in a feedback loop until convergence is achieved. First, maintenance tasks are grouped into checks through an optimization model that balances the yield of the parts' lifespan and the cost of having an airplane on the ground. Next, the duration of these checks is estimated using predictive analytics tools, historical data, and expert information. Finally, a scheduling model constructs an optimal long-term plan connecting and coordinating all these models. The feedback loop is completed by reviewing and refining outputs from the final stage. Our approach has been shown to reduce strain on key resources, increase fleet availability, and lower overall cost compared to a schedule built with standardized checks, without compromising the safety constraints set by the airline or the aircraft manufacturers.

Speaker: Jingzhe Lei
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Title: An Order Statistics Perspective for Systems Reliability

Abstract: This study proposes a novel reliability analysis framework from the perspective of order statistics. The methodology decomposes the survival function into two interpretable terms: 1) Order statistics-based failure distribution representation: This term leverages structural engineering paradigms and characterizes component failure sequences as ordered events, facilitating analytical tractability under the heterogenous components assumption or dependence modeling. 2) Survival signature-based system structure extraction: This term extracts topological system information without minimal path/cut set enumeration, ensuring computational scalability. The framework advances conventional reliability techniques in two key dimensions. First, it eliminates the computational burden of exhaustive minimal path/cut set enumeration inherent to structure function- and signature-based approaches. Second, it enhances interpretability by reformulating failure distributions through order statistics. These innovations collectively establish a versatile theoretical foundation for reliability characterization and a data-adaptive tool for non-parametric inference.

Speaker: Yao Lu
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Title: Assessing Heterogeneity in Step-Stress Accelerated Life Testing: A Homogeneity Test for Mixture Models with Censoring

Abstract: Step-stress accelerated life testing (SSALT) is a type of accelerated life testing (ALT) in which stress levels progressively increase at predefined time points. While statistical models for SSALT, assuming homogeneous populations, have been extensively explored, less attention has been paid to SSALT in heterogeneous populations, particularly when group membership is unknown and test units form disjoint groups. Such heterogeneous SSALT (hSSALT) experiments can be effectively modeled using a mixture approach. Although the hSSALT model provides more reliable extrapolations at the user level in the presence of heterogeneity and censoring compared to the standard SSALT model, it also requires greater computational effort due to the use of an adapted EM algorithm. Therefore, developing a homogeneity test to assess the necessity of adopting the hSSALT framework is both relevant and important. To address this challenge, we propose a likelihood ratio test for homogeneity in mixture models under censoring, focusing on two-component exponential mixtures. The test evaluates homogeneity against a two-subpopulation alternative, while accounting for both Type-I and Type-II censoring. Through simulation studies, we derive critical values and validate the proposed test using simulated hSSALT datasets. Additionally, we conduct power analyses and demonstrate the effectiveness and practical applicability of the proposed test using real-world datasets from the literature.

Speaker: Kai Hencken
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Title: Bayesian Analysis of Different Models of the Breakdown Probability of Vacuum Interrupters

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Abstract: Vacuum interrupters play a key role in the protection of the electric grid and its reliability. They need to be able to withstand high voltage surges with a high probability. Therefore, vacuum interrupters are regularly tested to guarantee this. It is well known, that the breakdown capability of the vacuum gap inside the device is of a stochastic nature and therefore its withstand or breakdown probability distribution needs to be determined by a sequence of tests based on the application of a surge with a random voltage level. It is well known that in such tests, the response seems to show a memory effect, meaning that the response of the device is changed by the history of breakdown and holds before. The origin of this behavior, but also the fluctuation of breakdown capability itself within the same device, is not well understood up to now. We show that by applying Bayesian analysis techniques and different physics-based models on a sequence of tests the origin can be investigated. This is based on using a Weibull model together with different ways how the scale parameter can depend on prior test results. We use different model comparison techniques to evaluate how well these models can explain the experimental results. These are based on a number of approaches using Bayes factor, information criteria in connection with cross validation, as well as, posterior predictive checks. The implication of this analysis on the testing strategy are discussed as well.

Speaker: Franck Corset
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Affiliation: Laboratoire Jean Kuntzmann & Université Grenoble Alpes (France)
Title: Bayesian inference for Imperfect condition-based maintenance for a gamma degradation process

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Abstract: The condition-based maintenance of a deteriorating system is considered. The degradation is modelled by a gamma process. The corrective actions are perfect and the preventive actions are imperfect or as bad as worse. The maintenance cost is derived considering a Markov-renewal process. The statistical inference of the degradation and maintenance parameters by Bayesian method is investigated and compared to the Maximum Likelihood Estimator. A sensibility analysis to different priors is carried out and the perspectives are detailed.

Speaker: Nicolas Bousquet
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Affiliation: EDF R&D, SINCLAIR Lab (France)
Title: Conservative estimation in structural reliability using surrogates

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Abstract: We consider the problem of computing consistent and conservative estimators of exceedance probabilities of a one-dimensional, decisional quantity, described as the output of some black box model, using machine learning-based surrogates. This problem is key for design and monitor critical systems and study the structural safety of these systems. After a review of available approaches, we examine the possibility of obtaining deterministic bounds for calculations based on surrogates, and then describe how the estimator thus obtained can be guaranteed to be relevant to the true probability associated with the black box model. This work takes advantage of recent results based on non-asymptotic control of estimators, through concentration inequalities.

Speaker: Marcelo Lagos
Email: marcelo.lagos.s@ug.uchile.cl
Affiliation: Universidad de Chile (Chile)
Title: Enhancing Fault Detection with Distributionally Robust Machine Learning Models

Abstract: Faults in mechanical or electrical components can cause disruptions in industrial applications, affecting operations and potentially leading to hazardous situations. Modern industrial systems are often equipped with sensors, enabling the use of data-driven techniques for fault detection. However, detecting or classifying faults using such algorithms can be challenging, particularly when the training data is noisy or limited. In this context, this talk explores the use of Distributionally Robust Optimization (DRO) to train classical machine learning models–such as support vector machines and logistic regression–for fault detection and classification. DRO seeks robust solutions by considering a set of possible perturbations to the empirical distribution, known as the ambiguity set, to account for the fact that the true underlying distribution is unknown and typically estimated from limited historical data. As a result, machine learning models trained with DRO often exhibit more reliable out-of-sample performance, making them potentially valuable tools for fault monitoring. The performance of the trained DRO models is evaluated on multiple publicly available datasets focused on fault detection and classification.

Speaker: Álvaro Lozano
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Affiliation: Universidad de Chile (Chile)
Title: Introducing WindOMS: Wind Operation & Maintenance Simulator Python Package

Abstract: Wind energy is becoming increasingly popular worldwide, offering a strong alternative that supports the decarbonization of power systems. However, the operational and maintenance (O&M) costs of wind farms remain substantial. As a result, numerous studies have focused on optimizing O&M and developing strategies to effectively coordinate maintenance and operation. The existing works, however, evaluate the performance of their proposed models using custom simulation engines, making it difficult to compare results across studies. This talk addresses that challenge by introducing Wind O&M Simulator (WindOMS)–a new Python package designed to evaluate the performance of O&M strategies in user-defined and easily replicable environments.

Speaker: Funda Iscioglu
Email: fundaiscioglu@gmail.com
Affiliation: Ege University (Turkey)
Title: Mean Residual Capacity Evaluation of a Multi-state k-out-of-n:G System

Abstract: In a binary weighted k-out-of-n:G system, each component in the system has a weight of wi and if the total weight of the system which is ∑wi (i=1,2,...n) is at least k, a pre-specified value, the system functions. The total weight of the system shows the performance of the system. Therefore, the overall change in the total performance of the system based on time has a special importance in the dynamic performance evalution of a system. Some recursive approaches are generally preferred to examine the dynamic change in some of the perfomance characteristics such as the mean residual capacity or the capacity loss of a system. Meanwhile recently, there have been also many researches dealing with the performance evaluation problem of a weighted multi-state k-out-of-n:G system structures. In particular in this study, the system is composed of n three-state components and each component in the system can experience perfect functioning, partial working, and complete failure states over time. Only minor degradation of components is considered and the system functions if the total weight of all the working components is at least k. We proposed a new recursive approach for the mean residual capacity of a weighted multi-state k-out-of-n:G system while it is working at a specific time. Also, in case the system is working, the capacity loss of the system is also provided. Keywords: weighted multi-state k-out-of-n:G system, mean residual capacity, capacity loss, order statistics.

Speaker: Sebastián Cáceres
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Affiliation: Universidad de Chile (Chile)
Title: Optimizing Operation and Maintenance in Wind Farms

Abstract: Over the past decade, the growth of the wind energy industry has driven significant interest in minimizing operation and maintenance (O&M) costs, which can account for as much as 15% to 30% of the total running cost of energy generated by wind turbines. In practice, O&M decisions are often made independently or in a sequential manner, which can lead to suboptimal O&M strategies that fail to capture the critical interactions between these activities. This presentation introduces a joint optimization model for O&M in wind farms. The problem is formulated as a stochastic mixed-integer linear program, incorporating the uncertainty inherent in both renewable generation and failures. The performance of the proposed model is evaluated in simulated environments using real-world data.

Speaker: Olivier Gaudoin
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Affiliation: Université Grenoble Alpes (France)
Title: Parametric estimation in an imperfect maintenance model with delayed corrective actions for left-censored data

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Abstract: A system is inspected at deterministic times and preventive maintenance actions are carried out at each inspection. If a failure occurs between two consecutive inspections, a minimal repair is carried out and the associated corrective action is done at the next inspection time. Therefore two types of maintenance actions are done at inspection times depending on whether or not a failure has occurred since the previous inspection. Both types of maintenance are assumed to be imperfect, of the ARA (Arithmetic Reduction of Age) type, with different parameters. In Cousino et al. (2024), the parameters of this model have been estimated for complete and interval-censored data. In the present paper, four methods are proposed to estimate the parameters for left- censored data. The quality of these methods is assessed through a simulation study. Finally, the methods are applied to analyze a real dataset from a gas transmission system operator.

Alejandro Mac Cawley
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Affiliation: Pontificia Universidad Católica de Chile (Chile)
Title: Predicting equipment degradation using sensor information in wine bottling lines

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Abstract: The PLASMA project, Platform for Systems Analytics and Advanced Maintenance, aims to refine and validate the models and predictive and prescriptive algorithms previously developed by the team and currently used by the ALMA Radio Telescope. It implements an intelligent cloud-based platform that supports the management and optimization of maintenance in production systems, with applications to a wide variety of industrial processes. We will present the initial results of the predictive failure algorithms that aim to predict the Remaining Useful Life (RUL) and projected probability distribution of equipment involved in bottling a large Chilean wine company. Several sensors were deployed in the equipment along with existing ones, obtaining historical information related to temperature, vibration, noise, production rate, stops, among many other data collected. We tested several filters to reduce noise and correlated the data with failure events. Unfortunately, the recorded failure events were only three, which did not allow us to perform any type of accurate prediction, and we are currently in the process of predicting equipment degradation trends.

Speaker: Magdalena Szymkowiak
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Affiliation: Poznan University of Technology (Poland)
Title: Preservation of the star and superadditive orders of homogeneous (id) component lifetimes by system lifetimes

Abstract: We describe conditions for preserving relations with given distributions in the star and superadditive orders of the mariginal distributions of identically distributed component lifetimes by semi-coherent system lifetimes. In particular, we specify the conditions for preserving the monotone generalized monotone failure rates on the average and generalized new better and worse than used properties. The conditions depend on the minimal cut sets of the system and the copula of dependence among the component lifetimes.

Speaker: Funda Iscioglu
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Affiliation: Ege University (Turkey)
Title: Reliability Analysis of Weighted Three-State System Structures Comprising an Application of Solar Panels

Abstract: Solar energy has recently become one of the important renewable energy sources in the world. The photovoltaic modules can have different performance levels depending on the solar radiation in the environment. In this study, the reliability evaluation problem of a solar panel system with weighted three-state photovoltaic modules is considered based on a solar radiation data set in one of the regions in Turkey. Reliability estimations are evaluated in terms of different number and types of photovoltaic modules for a solar panel system. Moreover, a new weighted multi-state (n-r+1, s)-out-of n system structure in which the working principle of the system is based on both the number of working multi-state components at different states and the related weights of the working components is proposed. This study is supported by the Scientific and Technological Research Council of Turkey, Project no:124F344/TUBITAK 1001. Keywords: weighted multi-state system, order statistics, solar panel system, photovoltaic module.

Speaker: Jarosław Warmbier
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Affiliation: Poznan University of Technology (Poland)
Title: Reliability functions measuring different aspects of aging process in memory subsystems

Abstract: This study explores reliability functions that measure various aspects of the aging process in memory subsystems, with a focus on data retention capabilities. As DRAM (Dynamic Random-Access Memory) technologies continue to scale over time to meet increasing performance and capacity demands, understanding their aging characteristics becomes essential for ensuring long-term reliability and optimal data retention in advanced computing systems. The research highlights the importance of identifying the lifetime distribution for data concerning time till failure of DDR5 (Double Data Rate, version 5) and LPDDR5 (Low Power Double Data Rate, version 5), the latest memory technologies. These estimations are crucial for memory controller design, which plays a pivotal role in maintaining robust performance and reliability in modern computing environments. Through a deeper understanding of aging processes contributes to enhancing the reliability and efficiency of memory subsystems.

Speaker: Nikolai Kolev
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Affiliation: University of São Paulo (Brazil)
Title: Reliability Interpretation of Discrete Line Integral on Uniform Grids and Applications

Abstract: In many real world models the original variables may be continuous in nature but discrete by observation. Nair et al. (2018) review a long list of methods in building multivariate discrete distributions, with reliability applications. In Kolev (2020) is introduced an alternative approach in generating families of bivariate discrete probability distributions with pre-specified properties, based on line integral of gradient vector on uniform grids. The method proposed is a new and powerful tool. It is a dicrete analogue of suggested by Marshall (1975) joint survival function exponential representataion of continuous joint survival function S(x,y) trough the line integral on an arbitrary smooth path starting at (0,0) and terminating at point (x,y) for x,y > 0. The functional form of the sum of gradient vector components r(x,y) plays a crucial role to describe the genuine nature of a process under interest. Kolev (2020) studies the case when r(x,y) has an additive representation. In the present work we will assume that r(x,y) has a multiplicative form. It will be shown how to build a huge class of corresponding well known and new bivariate discrete probability models. Reliability applications will be discussed as well.

Speaker: Anna Dembińska
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Affiliation: Warsaw University of Technology (Poland)
Title: Residual lifetimes and inactivity times of components upon system failure

Abstract: Let us consider a coherent system consisting of non-repairable components. Of practical interest are residual lifetimes of these components which survived the breakdown of the system. Indeed, if after the failure of the system, there are still functioning components, then we may consider to reuse them for other purposes. To judge whether it is reasonable to utilize them again, we need information on their residual lifetimes upon system failure, i.e. on the times that will elapse from the system breakdown until their failures. A dual concept to residual lifetimes upon system failure are inactivity times (also referred to as passed lifetimes) of components upon system failure. They represent times that passed from failures of non-surviving components to the breakdown of the whole system. They are related to autopsy data. In particular, they are useful for predicting missing observations. During the talk, I will assume that the joint distribution of component lifetimes is exchangeable and absolutely continuous thus allowing dependence among components. I will show that, under this assumption, both residual lifetimes and inactivity times of components upon system failure do not depend on the structure of the system. I will also present formulas describing distributions of the residual lifetimes and inactivity times of interest. Next, I will use a copula to model the dependence structure among components and will express these formulas in terms of this copula. Finally, I will demonstrate some numerical results and will give examples of application of the theoretical derivations.

Speaker: Hassane Chraibi
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Title: Stochastic MRAS-Based Strategy Optimization: Integration into PyCATSHOO, a Platform for Probabilistic Performance Assessment of Complex Systems

Abstract: This paper presents the integration of the stochastic version of the Model Reference Adaptive Search (MRAS) algorithm with a modeling approach based on piecewise deterministic Markov processes (PDMPs) for the analysis of complex systems. Implemented in the PyCATSHOO platform, this approach enables the modeling and performance evaluation of hybrid systems characterized by both discrete stochastic and continuous deterministic behaviors. To demonstrate the effectiveness of this integration, a case study is conducted to optimize the maintenance strategy of a multi-component system affected by aging. In this case study, component failure rates increase with both actual and apparent ages–the latter reflecting the components' operational time. Maintenance actions–such as replacements and refurbishments–can reset these ages, thereby reducing failure rates. The optimization process takes into account the costs of these actions, along with the corrective action costs and the revenues generated by operating the system, to calculate an objective score that must be maximized. By leveraging the MRAS algorithm within PyCATSHOO, this study determines the optimal (or near-optimal) scheduling of maintenance interventions over the system's operational lifetime. However, the study also confirms the algorithm's sensitivity to hyper-parameters, which must be properly tuned to ensure effective execution and reliable results. Furthermore, the study underscores the advantages of this approach–particularly the ease of modeling and the straightforward expression of optimization objectives and constraints–made possible by a complex-system modeling platform that integrates dedicated optimization procedures.

Speaker: Diana Rauwolf
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Affiliation: RWTH Aachen University (Germany)
Title: The inspection paradox and renewal theorems with random time

Abstract: Various processes in technical systems, quality control as well as in finance, insurance or real life may be modelled by means of renewal processes. When we inspect such a renewal process at a given time t, an effect occurs which is known as the (classical) inspection paradox. It states that the renewal interval containing t, the inspection interval, say, is stochastically larger than a common renewal interval (Feller 1971; Ross 2003). The inspection paradox arises in the abovementioned situations and applications, e.g., when we successively replace components of the same type upon their failures in a technical system, when we wait for a bus or metro to arrive or when we observe consecutive production times of technical facilities. By introducing a random time of inspection T independent of the renewal process, we are able to obtain a deeper insight into the inspection paradox via representations of the expected length of the inspection interval and related inequalities (cf. Rauwolf and Kamps 2023). Furthermore, we consider fundamental asymptotic theorems in renewal theory such as Blackwell's theorem in the context of random inspection times, the latter theorem referring to the expected number of renewals in an interval of fixed length starting at the random time T.

Speaker: Felipe Miranda
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Affiliation: Universidad de la República (Uruguay)
Title: Uniformly most reliable stochastic binary systems in separable systems

Abstract: The goal of this talk is to extend well-known concepts and results from the theory of network reliability into the more general framework of stochastic binary systems. In 1986, Frank Boesch introduced the concept of uniformly most reliable graphs, proposing several conjectures which shaped the study of uniform reliability analysis. One of these conjectures, known as the 0-element conjecture, states that each uniformly most reliable graph has the least number of k-edge-cuts for any feasible choice of k. In this talk, we will first revisit some key concepts related to stochastic binary systems such as subsystems, coherence, separability and uniform reliability. Next, we will show that any subsystem of a separable stochastic binary system is also separable. Then, we will restate the 0-element conjecture in the context of stochastic binary systems. Finally, we will prove that the 0-element conjecture holds for any subsystem coming from a separable coherent stochastic binary system.

Speaker: Dora Jiménez
Email: doramariela@gmail.com
Affiliation: Universidad Mayor (Chile)
Title: When the Power Fails, Communication Suffers: Modeling Earthquake Impacts on REUNA and SEN Infrastructure in Chile

Abstract: In this talk, we explore the reliability of a fiber-optic telecommunications network subject to seismic hazard, with a particular focus on its operational dependence on the electrical power grid. Earthquakes can trigger simultaneous failures in multiple interconnected infrastructures, leading to cascading effects and extended recovery times. We present a model that integrates probabilistic seismic hazard analysis (PSHA), fragility functions, and graph-based representations to assess how disruptions in the power grid affect the performance and recovery of the telecommunications network. Our case study focuses on REUNA and SEN, two real networks operating across the seismic-prone territory of Chile. We highlight the consequences of different pre-earthquake operating conditions in the electrical system and their impact on network recovery and connectivity metrics. This work emphasizes the importance of considering infrastructure interdependencies in risk modeling and supports the development of integrated strategies for resilient network design and emergency response planning.

Speaker: Federico Méndez
Email: fedemezuga3@gmail.com
Affiliation: Universidad de la República (Uruguay)
Title: Model Construction in Stochastic Binary Systems

Abstract: A Stochastic Binary System (SBS) is a mathematical model representing a multicomponent on-off system, where components are subject to random failures. While previous studies have typically assumed perfect information about the system, this work focuses on a data-driven approach to model construction. Specifically, we develop and evaluate machine learning (ML) and deep learning (DL) models to approximate the function of an SBS using only a random subset of its possible states. The primary objectives are to maximize accuracy on a test set and investigate trade-offs between accuracy, computational efficiency, and model complexity. Furthermore, we analyze the generalizability of the models by evaluating their performance on all possible unobserved states of the system. Experimental results are promising, with some models achieving perfect accuracy across all possible states in systems of moderate size, demonstrating the effectiveness of this approach for approximating stochastic systems.

Speaker: Longcheen Huwang
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Affiliation: National Tsing Hua University (Taiwan)
Title: A rank-based EWMA chart for monitoring linear profiles when the random error is not normally distributed

Abstract: Profile monitoring of statistical process control is a technique for monitoring the stability of a functional relationship between a response variable and one or more covariate variables over time. The monitoring of linear profiles is the most important one because the response variable and the covariate variables are usually correlated with linearity due to its flexibility and simplicity. Additionally, most of existing charting methods for monitoring linear profiles assume that the random error is normally distributed. However, the normal assumption of the error term is not justified in certain applications. This causes the existing charting methods both inadequate and less efficient for monitoring linear profiles. In this talk, based on the rank-based regression, we develop a charting scheme for monitoring linear profiles where the random error is not assumed to be normally distributed. The charting scheme mainly applies the exponentially weighted moving average technique to the spatial rank of the vector of the Wilcoxon-type rank-based estimators of regression coefficients and an error variance estimator. Performance properties of the developed control chart are evaluated and compared with a multivariate sign charting scheme in terms of the out-of-control average run length. A real example is also used to illustrate the applicability and implementation of the proposed charting method.

Speaker: Pedro Luiz Ramos
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Title: Statistical Inference for Partial Imperfect Repair Models

Abstract: In this talk, we will introduce Partial Imperfect Repair (PIR) models, a flexible framework for assessing the reliability of repairable systems under partial and imperfect maintenance scenarios. We will present both classical and Bayesian estimation procedures for PIR model parameters, detailing our choice of priors and the likelihood-based approach. Through a comprehensive Monte Carlo simulation study, we will compare estimator performance, bias, mean squared error, and coverage probability, and highlight the comparative strengths of each method. Finally, we will discuss practical guidelines for applying these techniques to real maintenance data and for designing predictive maintenance schedules.

Speaker: Wei-Chang Yeh
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Affiliation: National Tsing-Hua University (Taiwan)
Title: Emerging Trends in Network Reliability: From Multi-State Systems to AI-Driven Solutions

Abstract: With the rapid evolution of interconnected systems, the reliability of complex networks has become a critical concern for numerous fields, including telecommunications, energy infrastructures, transportation networks, and more. This special session aims to bring together researchers and practitioners to discuss emerging trends in network reliability, with a focus on: Multi-State Systems (MSS) and their modeling approaches. The application of Artificial Intelligence (AI) and machine learning techniques to assess, predict, and enhance network reliability. Cutting-edge advances in probabilistic, statistical, and computational methods for large-scale network analysis. Implementation challenges in real-world networked systems, covering both academic research and industrial case studies. By showcasing novel theoretical frameworks, computational techniques, and data-driven innovations, this session seeks to encourage interdisciplinary collaboration and to highlight future research directions in the field of network reliability.

Posters

Author: Christian Davidson
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Affiliation: Universidad Adolfo Ibáñez (Chile)
Title: Bayesian estimation of a survival function under invariance conditions

Abstract: In this work, we present a nonparametric Bayesian approach for estimating the survival function of a system whose components are arranged in series, also known in the literature as a competing risks model. A major challenge in nonparametric Bayesian estimation lies in the vastness of the parameter space over which the prior distribution acts. It is therefore necessary to restrict this space by incorporating additional information, such as symmetry or invariance properties, which are often known about the survival function or its components. To this end, we consider a multivariate invariant Dirichlet process–introduced here for the first time–as a class of prior distributions for the vector formed by the system's sub-survival functions. Based on Peterson's functional, we obtain a nonparametric Bayes estimator for the system's survival function under quadratic loss, and we study its asymptotic properties.

Author: Nataly Martínez
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Affiliation: Pontificia Universidad Católica de Chile (Chile)
Title: Bayesian Inference for the Partial Imperfect Repair Model

Abstract: Over the past decades, technological advances have significantly improved industrial processes. However, they have also introduced new challenges in the field of reliability, particularly in the modeling of repairable systems. One of the most critical issues is the proper representation of imperfect repairs, as many do not restore the system to its original condition. A rigorous analysis of these systems enables the design of more effective maintenance policies, extending equipment lifespan and reducing operational costs. It has been observed that traditional frequentist approaches may present significant limitations, such as highly biased estimates for small samples and the inability to obtain credible intervals. This project proposes the use of Bayesian inference to address the Partial Imperfect Repair (PIR) model–a recent contribution to the literature noted for its flexibility and independence from asymptotic properties. In this context, Bayesian inference may offer a solid and promising alternative. The proposed approach will employ noninformative prior distributions, which are fundamental to the inferential process. The feasibility of the method will be assessed through Monte Carlo simulations, comparing it with classical methods using metrics such as accuracy, bias, and computational efficiency. The implementation will be carried out in Stan, using MCMC algorithms. The goal is to develop a methodology that provides more precise and robust estimates, thereby improving the understanding of failure behavior in repairable systems.

Author: Jesús Chaffe
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Title: Enhancing Fault Tolerance in Optical Networks with DRL-Based 1+1 Protection: A Resilience-Driven Approach

Abstract: As optical networks evolve to support ever-increasing traffic demands, ensuring uninterrupted service despite failures has become critical. Fault tolerance mechanisms are essential to prevent service disruptions that can have severe operational and economic consequences. In this work, we present a Deep Reinforcement Learning (DRL) agent that proactively enhances network resilience by transmitting each connection request simultaneously over two distinct paths: a primary and a protection path. The primary path is selected as the first available shortest route, while the protection path is dynamically optimized by the agent to minimize the blocking probability across the network. We benchmark our agent against two traditional heuristics: Classic 1+1 protection, with static precomputed routes, and Heuristic 1+1 protection, which dynamically selects the two shortest available paths at request time. Evaluations on the NSFNet topology, considering both fault-free conditions and a critical link failure (link 8-9), demonstrate that our DRL-based approach consistently achieves lower blocking probabilities, showcasing its superior ability to maintain high service availability even under adverse conditions.Bayesian inference may offer a solid and promising alternative. The proposed approach will employ noninformative prior distributions, which are fundamental to the inferential process. The feasibility of the method will be assessed through Monte Carlo simulations, comparing it with classical methods using metrics such as accuracy, bias, and computational efficiency. The implementation will be carried out in Stan, using MCMC algorithms. The goal is to develop a methodology that provides more precise and robust estimates, thereby improving the understanding of failure behavior in repairable systems.

Author: Marco Capaldo
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Title: Lifetimes analysis through new Gini's índices

Abstract: The Gini's mean difference and the Gini's index are two popular dispersion indices because they quantify how far a random variable and an its independent copy are, see Arnold and Sarabia. Recently, new multivariate Gini's indices have been defined and studied in Capaldo and Navarro. Aiming to apply them in reliability theory, they have also introduced efficient versions for any semi-coherent system. Moreover, Capaldo et al. [3] have employed bivariate Gini's indices in order to handle the distance between the lifetimes of two systems having shared components. Further distance minimizing problems have been discussed in Capaldo et al. [2]. Along the research lines described above, we provide an overview on such new Gini's indices with applications in system reliability theory.

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Title: Multivariate Birnbaum-Saunders accelerated lifetime model with dependence structure modeled via copulas and frailty

Abstract: In recent years, Birnbaum-Saunders regression models have been frequently studied. One of the main premises in traditional regression models is the assumption of independence between observations, which is also the case in survival analysis studies, in which the independence between the survival times of distinct individuals is considered. However, in some cases, this assumption is not valid, as in the case of events observed in the same individual. Multivariate regression models with a dependence structure are a possible alternative for modeling data of this type. In view of this, we propose, in this work, a new multivariate Birnbaum-Saunders accelerated lifetime model, in which the dependence structure was modeled via frailty and through the use of copulas. We used the maximum likelihood estimation method to estimate the parameters of the proposed model. Some simulation studies were developed to evaluate the performance of the estimators. In addition, we proposed some residuals and derived diagnostic measures under the local influence approach. To illustrate the methodology developed, we used a set of real data.

Author: Cristóbal Reyes
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Title: Optimal Repair Policies for Coherent Systems with Simultaneous Failures

Abstract: This work addresses the problem of optimizing repair policies in multicomponent systems subject to stochastic degradation. To do this, we adopt a framework based on Markov Decision Processes (MDPs), which enables the modeling of system evolution and the formulation of maintenance decisions aimed at maximizing operational availability while minimizing associated costs. The dynamics of simultaneous component failures and breakdowns are modeled using the Lévy-Frailty Marshall-Olkin (LFMO) distribution, which captures dependencies among component lifetimes due to exposure to a common failure environment. This distribution provides a suitable structure for representing random shocks that may render multiple components inoperative at once, a typical feature in real-world industrial settings. We model the process as an MDP in order to derive various optimal repair policies adapted to the system's behavior under different degradation patterns and cost structures. In particular, we employ value iteration methods to solve the MDP in scenarios with known state spaces, and we use simulations to analyze and assess the performance of the obtained solutions.

Author: Dora Jiménez
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Title: Reliability Assessment of Critical Healthcare Infrastructure under Seismic-Induced Failures

Abstract: This work presents an ongoing assessment of the reliability of critical healthcare infrastructure under seismic-induced failures using Probabilistic Seismic Hazard Analysis (PSHA). The study focuses on public healthcare centers in Santiago, Chile, including primary, secondary, and tertiary levels of care. Our aim is to evaluate not only the structural vulnerability but also the potential social impact, quantified by the number of patients that could be affected during seismic events. As part of the methodological development, we employ a Gaussian Mixture Model (GMM) to synthetically generate depth data based on the observed bimodal distribution, enhancing the robustness of the hazard representation. This preliminary work seeks to support improved preparedness and risk mitigation strategies for healthcare systems in earthquake-prone regions. Keywords: reliability, critical infrastructure, simulation, earthquakes, PSHA, healthcare systems.

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Title: Rumor model in inhomogeneous random trees with highly connected nodes

Abstract: In the field of network theory, a node is defined as a vertex that has a significantly larger number of neighbors compared to other vertices in the network. This work proposes a stochastic model, formulated as a continuous-time Markov chain, with the aim of analyzing, from a theoretical perspective, how the distance between nodes influences the dissemination of a rumor within a network. The population considered is represented by a inhomogeneous random tree, composed of nodes of degree k and vertices with a maximum degree given by d(k).

Author: Abigail Medina
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Affiliation: Universidad Adolfo Ibáñez (Chile)
Title: Seismic Vulnerability Assessment of Venezuela's Telecommunications Network Using Probabilistic Risk Analysis

Abstract: In recent decades, telecommunication networks have consolidated as essential infrastructures for connectivity, communication, access to information and quality of life in general, especially due to the constant increase of tools and functionalities that require the use of internet services. This is why the study of the response and vulnerability of these infrastructures to natural disasters, particularly earthquakes, is becoming more relevant. Venezuela, although not usually perceived as a highly seismic country, is exposed to significant risks due to the interaction of the Caribbean and South American tectonic plates. In addition to this, a large part of its population and critical infrastructure is located in the most seismically active zones. This study evaluates the vulnerability of the Venezuelan telecommunications network to seismic events through a three-stage probabilistic seismic risk model. The first stage simulates earthquake scenarios, the second estimates ground motion using spectral acceleration, and the third calculates the marginal probability that network components exceed specified damage states–light or extensive–through the application of fragility curves and Monte Carlo simulation. Results reveal that eastern, central, and capital regions are more prone to network disruption. Despite data limitations requiring several assumptions (notably for network topology and geolocation), this model offers a solid framework for future risk mitigation strategies.

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Title: Sustainable Predictive Maintenance: Balancing Circularity and Spare Parts Availability Within Finite Maintenance Horizons

Abstract: The optimization of predictive maintenance models is a critical challenge in the industrial vehicle sector, particularly when considering constraints like resource management, circularity, and customer expectations. This research focuses on developing an optimized predictive maintenance model that explicitly integrates these operational constraints. Circularity enables the replacement of components with remanufactured or reconditioned parts in addition to new ones, while availability constraints account for stock levels of both new and remanufactured parts. The goal is to optimize maintenance decisions, enhance operational efficiency, and reduce costs while meeting customer expectations for reliability. The maintenance model will operate over a finite horizon, aligned with the duration of the maintenance contract. Initially, we will define remanufactured components and evaluate their impact on system degradation. The model will then integrate parts availability into decision-making, adapting maintenance policies based on stock levels. Furthermore, we propose considering vehicle recovery after the contract term, optimizing maintenance costs throughout the contract's lifecycle, including scenarios where the vehicle is retained post-contract. Simulations using dynamic programming will be conducted to evaluate the performance of the proposed maintenance policy and assess the benefits of incorporating circularity and availability constraints. This approach enables a more comprehensive model, providing additional gains and better-planned workshop interventions. In conclusion, this study demonstrates how predictive maintenance can be optimized by integrating circularity and parts availability within a finite maintenance horizon. The approach ensures cost-effective, environmentally sustainable maintenance decisions that balance operational efficiency and resource availability, supporting a robust framework for sustainable predictive maintenance.

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Title: Generating Censored Data with Tunable and Real-World-Like Properties

Abstract: A common challenge in survival analysis is the presence of (right) censored instances, where the event of interest does not occur within the study period. The censoring rate varies across application domains and can significantly influence model performance. To extend, develop, and test new models in a specific domain, it is crucial to simulate survival datasets with a desired censoring rate. Existing approaches often rely on arbitrary censoring time generation or simplified parametric models (e.g., exponential distribution), which do not necessarily reflect the censoring characteristics observed in real-world datasets. In this paper, we propose a novel approach for simulating semi-synthetic survival datasets with predefined censoring rates. Our method ensures a close approximation to the original censoring distribution while allowing precise control over the censoring rate. We demonstrate that our approach effectively generates realistic censoring times by leveraging the relationship between censoring and covariates, outperforming existing methods in terms of distributional fidelity. Quantitative evaluations using the Wasserstein distance assess how well the censoring times generated by our method align with a reference distribution that represents the real censoring mechanism. We compare this distance to those obtained with existing approaches, demonstrating that our method produces censoring times that more faithfully reflect real-world censoring patterns.

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