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Book of Abstracts

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Preface

Dear colleagues and friends,

We are pleased to present the Book of Abstracts for the ENBIS Spring Meeting 2026, held in the historic city of Granada.

This volume brings together the diverse and cutting-edge contributions centered around the theme: **"Reliability, maintenance and safety in the data-driven era"**.

As we all know, in a context of increasing system complexity, digital transformation, and growing societal demands for safety, resilience, and sustainability, the field of reliability and maintenance engineering is undergoing a profound evolution. The contributions gathered in this Book of Abstracts showcase how data, models, and algorithms are transforming the design, monitoring, and maintenance of engineering systems. It is inspiring to see both the advancement of traditional reliability models and the push towards new boundaries using AI-based methods for smarter, more adaptive systems.

In addition to exploring these specific methodologies, our goal for this Spring Meeting is to serve as a cross-disciplinary platform. We hope to encourage vibrant discussions on strategic challenges and to facilitate a dynamic exchange of ideas that promotes scientific advancement and its effective translation into practical solutions.

None of this would be possible without the collective effort of our community. We would like to express our deepest gratitude to the **European Network for Business and Industrial Statistics** (ENBIS) for their support. We are also highly indebted to our sponsors and partner institutions, whose generous backing has made this event a reality.

Finally, our most sincere thanks go to the participants for sharing their cutting-edge research and strategic insights. We extend a special note of gratitude to our keynote speakers, Prof. Nikolaos Limnios and Prof. Anne Barros, for their invaluable contributions to the program.

The Organizing Committee
ENBIS Spring Meeting 2026
Granada, 28-29 May

Lévy–Frailty Marshall–Olkin (LFMO) distribution, which captures both individual component failures and simultaneous failures caused by common shocks through an underlying stochastic degradation process..The maintenance decision problem is formulated as a sequential decision-making problem. Starting from the continuous-time reliability model, we construct a Semi-Markov Decision Process (SMDP) under an average-cost performance criterion. The SMDP is then transformed into an equivalent discrete-time average-cost Markov Decision Process (MDP), allowing the use of dynamic programming methods to compute optimal or near-optimal maintenance policies.Because the transition dynamics of the system can be complex or analytically intractable, we also develop a simulation-based approach to approximate the underlying MDP. In particular, we employ reinforcement learning techniques based on the Stochastic Approximation Value Iteration Algorithm (SAVIA) to estimate optimal policies using simulated trajectories of the LFMO process.In addition to the policies obtained through the MDP formulation, we also study and compare several alternative maintenance strategies. These include simple rule-based policies that depend on aggregate system indicators, such as the number of failed components. Although such policies are generally less optimal than those derived from the MDP framework, they are computationally inexpensive and scale well to larger systems. Simulation experiments show that, despite their simplicity, these heuristic policies can sometimes achieve competitive performance, making them attractive practical alternatives when solving the full MDP becomes computationally challenging.Computational experiments illustrate how the dependence structure among failures affects maintenance decisions and demonstrate the effectiveness of the proposed framework for designing and evaluating maintenance policies in complex reliability systems.

A data-driven health indicator for condition monitoring of electric vehicles

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The increasing availability of high-frequency telemetry data in electric vehicles (EVs) creates new opportunities for monitoring system health. Within the broader context of Prognostics and Health Management (PHM), these data streams have the potential to facilitate the transition from reactive maintenance to evidence-based condition assessment. However, in real-world industrial settings, reliable labels for faults, maintenance interventions or remaining useful life (RUL) are often incomplete, inconsistent or unavailable. This restricts the effectiveness of supervised predictive modelling and necessitates the development of statistical approaches that can operate without explicit degradation benchmarks.This work proposes a data-driven framework for developing a Vehicle Condition Indicator (VCI): an interpretable, synthetic measure of vehicle health derived from heterogeneous, multisensory telemetry. The framework's primary methodological contribution is the definition of a statistically robust indicator that can capture deviations from normal behaviour while remaining stable under different operating conditions.The framework integrates multivariate statistical monitoring and unsupervised learning techniques into a consistent modelling approach. In particular, baseline operating regimes are identified through dimensionality reduction and clustering to characterise nominal system behaviour. This modelling step enables normal variability due to usage conditions to be separated from structurally atypical behaviour. Any deviations from these patterns are quantified using metrics based on distance and density, and their temporal evolution is analysed to distinguish persistent shifts, which may be associated with degradation processes, from transient anomalies.The resulting VCI is not intended to be a black-box score. It is designed to be interpretable and can be broken down into subsystems, such as the battery, power electronics or braking system. This breakdown provides diagnostic proxies that support engineering analysis, even when labelled failures are absent. Rather than directly estimating RUL, the indicator provides a continuous, comparable measure of relative condition which can be monitored over time and across vehicles operating under different duty cycles, thus supporting PHM decision processes without relying on fully supervised degradation models.A case study based on real-world EV telemetry data illustrates the statistical properties and practical relevance of the proposed indicator. The analysis shows how the VCI captures emerging behavioural changes before explicit faults are recorded, enabling consistent health ranking across vehicles with different usage profiles. Although it was developed for EVs,

the framework can easily be transferred to other complex industrial systems characterised by high-dimensional telemetry and scarce labels. By basing condition monitoring on interpretable multivariate statistics rather than purely predictive modelling, this work aims to stimulate discussion within the business and industrial statistics community on robust and scalable approaches to data-driven health assessment.

Monotonicity-based parent-child inference for the efficient computation of signatures and minimal cut/path sets in coherent systems

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In binary reliability systems, the minimal cut-sets, path-sets and signature vector [1, 2], provide the basis for computing key reliability measures, such as the survival function and the mean time to failure [1, 3]. However, these quantities are typically obtained by exhaustive evaluation of the structure function over the Boolean state space 1, whose size grows exponentially with the number of components: if n is the number of components in the system, there are 2^n possible states of the system 2. Thus, as system size increases, this becomes computationally burdensome, and exact calculation becomes practically impossible even for moderate-sized systems.In this work, we propose a new method to compute minimal cut-sets, path-sets and the signature vector for monotonous binary systems. We make no assumptions about the structure of the system and consider its structural function a black box. The proposed approach explores the Boolean state space by failure level, defined as the number of failed components. At each iteration, a level is selected from an adaptive biased distribution, then an "unchecked"state within that level is sampled uniformly at random and evaluated using the structure function, and then its status (working or failed) is propagated through the state lattice using monotonicity-based parent-child inference 2. Indeed, if the sampled state is working, all of its ancestors toward lower failure levels are inferred working; and if it is failed, all of its descendants toward higher failure levels are inferred failed. In this way, a single exact evaluation can determine the status of many additional states without further structural-function calculations. With this, we propose confidence intervals for the signature vector. And in the cases where all states can be checked, we can compute the minimal cut- and path-sets, and also the signature of all intermediate states.Preliminary results across multiple tested systems indicate a substantial reduction in computation time when using our algorithm.1 F. Samaniego, System Signatures and their Applications in Engineering Reliability. Springer, 2007.2 J. Navarro, Introduction to System Reliability Theory. Springer, 2022[3] J.-L. Marichal, P. Mathonet, and T. Waldhauser, "On signature-based expressions of system reliability,"Journal of Multivariate Analysis, vol. 102, no. 10, pp. 1410–1416, 2011.

Implementation of automatic differentation on maintenance optimization problems

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