IV International Conference on Optimization, Learning Algorithms and Applications

Book of Abstracts

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OL2A 2024

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Welcome

Welcome to OL2A 2024 - International Conference on Optimization, Learning Algorithms and Applications.

OL2A offers a forum for the research community on optimization and learning to get together and share the latest developments and techniques as well as develop new paths and collaborations. OL2A provides a broad scope of presentations, covering many areas of optimization and learning and state of the art applications to multi-objective optimization, optimization for machine learning, machine learning for optimization, optimization and learning under uncertainty and fourth industrial revolution.
It is with great pleasure that the Organizing Committee welcomes you all to OL2A 2024!

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Invited Plenary Lectures

AI & GenAI: Principles, Applications, Challenges

Eugénio Oliveira

Biography: Eugénio Oliveira is Full Professor (Artificial Intelligence) at the University of Porto (UP). Co-founder of LIACC (Artificial Intelligence and Computer Science Laboratory) at UP. He created and chaired PRODEI, the PhD Program on Informatics Engineering at UP. He got his PhD in Artificial Intelligence at New University of Lisbon in 1984. He was awarded with the Gulbenkian Prize for Science and Technology. "Guest Academic" at IBM/IEC in Belgium (84-85). In the seventies was R&D Engineer at Brown Boveri, Switzerland. Area chair for Agents in the European Conference on Artificial Intelligence - ECAI 2008. General co-Chair for EPIA- AI Conference in 2017. He successfully supervised 23 PhD students and more than 60 Master students. Member of the Scientific Council for New Talents in AI at the Gulbenkian Foundation. He was involved in research projects, funded by either national or international funding agencies concerning AI and mutiagent systems applications. Current topics of interest include AI and Ethics, NLP, Software Agents Trust Models, Adaptive Agents for E-Business, Intelligent Transportation Systems, "Emotional-like" Agents, Agent's Strategies for Co-operation and Negotiation. His scientific work has more than 6000 citations and híndex 38 at Google Scholar.

Abstract: We will talk about AI and Generative AI fundamentals, applications impact, challenges and limitations. Gen AI Architectures and applications will be presented and analyzed together with the main foreseen uses for a Beneficial AI as well as the potential dangerous impacts in society. We will emphasize the need of an AI for a sustainable environment versus excessive energy consumption and questionable military applications. We will also remember the need for explicit legislation on AI development, deployment and use, all around the world. We will finish with few comments on the polemic possibility for an Artificial General Intelligence.

Stress-testing Algorithms via Instance Space Analysis

Verónica Bolón Canedo

Biography: Verónica Bolón Canedo received her B.S. (2009), M.S. (2010) and Ph.D. (2014) degrees in Computer Science from the University of A Coruña (Spain). After a postdoctoral fellowship in the University of Manchester, UK (2015), she is currently an Associate Professor in the Department of Computer Science and Information Technologies of the University of A Coruña. She received the Best Thesis Proposal Award (2011) and the Best Spanish Thesis in Artificial Intelligence Award (2014) from the Spanish Association of Artificial Intelligence (AEPIA). She has extensively published in the area of machine learning and feature selection. On these topics, she has co-authored two books, seven book chapters, and more than 100 research papers in international conferences and journals. She co-organized several special sessions at international conferences, such as ESANN and IJCNN, and served in program and scientific committees. Her current research interests include machine learning, feature selection and green algorithms. She has served as Secretary of the Spanish Association of Artificial Intelligence and is member of the Spanish Young Academy and the Royal Academy of Sciences of Spain.

Abstract: In this talk, we will delve into the critical role of feature selection in managing big data. We will discuss the challenges posed by large datasets and the need for preprocessing to ensure data quality and learning efficiency. The presentation highlights dimensionality reduction techniques, distinguishing between feature extraction and feature selection - transforming or selecting features to enhance model performance. We will also explore different feature selection methodologies, including filters, wrappers, and embedded methods, emphasizing their impact on model transparency and interpretability. The talk concludes by addressing future challenges in feature selection, particularly in deep learning and data bias, and the need for scalable methods.

Special Sessions

LEE - Learning Algorithms in Engineering Education

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Description: The world is changing. Constant technological advances allow for different approaches to teaching. Since Science (e.g. Mathematics, Physics) is a core subject in engineering courses, we intend to highlight the utmost approaches (using learning or optimization methods) in its teaching for engineering students. Technological advances and sometimes real world problems induce us towards new methodologies and trends, not only in engineering but also in more general contexts. Therefore, research works about learning or optimization methods applied to the educational field are, in general, welcome. Thus, this session focuses on learning algorithms applied to the area of education, e-learning platforms, blended learning, and management systems learning, among others.

Topics: Learning algorithms applied in education · Intelligent systems for education · Innovative learning systems and innovative teaching systems · Case studies

OSDG - Optimization in the SDG Context

Organizers:

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Description: Nowadays optimization significantly contributes to the success of companies. Our vision is that they can also have the same potential to contribute to non-profit organizations, humanitarian issues and societal challenges. The Sustainable Development Goals (SDG) are 17 goals promoted by United Nations with the aim of create balance between social, economic and environmental sustainability. It comprises several aspects of society, such as health, education, clean energy and water, innovation and infrastructures, industry and sustainable cities, among others. Thus, research works on optimization methods applied to non-profit organizations or SDG, are welcome.

Topics: Optimization · Green industry · Applications of sustainable development goals (SDG) · Case studies in non-profit organizations

OCSD - Optimization in Control Systems Design

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Description: Optimization is currently applied to a myriad of different knowledge areas that span from economic applications to social sciences. In the control engineering framework, optimization plays a fundamental role in several design strategies such as predictive, fuzzy, decentralized and optimum control among many, many more. Moreover, due to the increased tendency of integrating soft-computing techniques into control loops, and since those methods frequently rely on optimization algorithms in order to be able to learn, adapt and react, optimization is fundamentally ubiquitous in the control engineering realm. Since many researchers are working in this area, it is fundamental to provide a vehicle for them to present their results and to foster a place where discussion regarding the use of optimization techniques in control can take place.

Topics: Control systems design · Optimization

MLAIR - Machine Learning and AI in Robotics

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Description: Robotics is a vast and complex knowledge field that includes the scientific concepts and principles of different areas of expertise, such as mathematics, physics, computer science, electronics, and mechanics. Since it is extensive, its challenges can be divided into different and active research areas. Despite being a relatively mature subject, it has much to evolve, especially in autonomous robotics. With the advent of machine learning (ML) algorithms, new and improved solutions are being proposed. One example is the application of embedded Machine Learning (also known as Edge ML), which allows local sensor data processing to improve robot perception and control. Although the current hardware is powerful enough to run power-hungry software, machine-learning techniques typically require high processing power and increased energy consumption. This situation creates a gap in implementing Edge ML and AI in equipment with limited processing power, energy, and connectivity, like autonomous robots. Therefore, this session welcomes machine learning works applied to robotics and its sensors, including those related to embedded ML, Edge ML, or Edge AI.

Topics: Robotics · Machine learning · Case studies · Deep learning · Embedded ML · Edge ML · Edge AI

Abstracts

Integrating Remote Sensing and Machine Learning for Accurate Detection of Agricultural Zones in El Jadida, Morocco

Allae Erraissi, Hafsa Ouchra and Mouad Banane

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This article presents an in-depth study on the detection and location of agricultural zones in El Jadida, Morocco. Accurate identification of these zones is crucial for sustainable land management and effective regional planning. To achieve this objective, a methodology integrating remote sensing techniques, geographic information systems (GIS), and machine learning algorithms was implemented. The results demonstrate the accuracy and reliability of this approach, providing essential information to decision-makers and agricultural stakeholders in the region. This study highlights the potential of remote sensing technologies to improve the mapping of agricultural areas, thus contributing to sustainable agricultural practices and optimal territorial planning. The methodological approach adopted involves the pre-processing of imagery data from Landsat 7 and 8 satellites, covering the city of El Jadida. We extracted the relevant features, divided them into training and test sets, and then applied three supervised learning algorithms: random forest (RF), support vector machine (SVM), and gradient boost tree (GTB). Through several experiments, we evaluated the performance of each machine learning method in terms of accuracy and Kappa coefficient for the years 2000 and 2020. We also analyzed changes in agricultural areas between these two periods. The results show that random forest is the best performing algorithm, with an accuracy of 98.14% in 2000 and 98% in 2020, and Kappa coefficients of 0.96 in 2000 and 0.95 in 2020.

Keywords: Remote sensing · Machine learning · Mapping agriculture · Classification · Agricultural areas

Speeding up Line Search For Composite Objective Function with a Linear Inside Part

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The paper illustrates a significant acceleration of the line search procedure for composite objective functions with a linear inside part. The memorization technique is used, and our implementation of the line search mostly uses directional derivatives instead of gradients. Numerical experiments predominantly employ the L-BFGS algorithm, leveraging our custom implementation. A series of tests showcase the effectiveness of this implementation. In targeted experiments, redundant calculations are excluded, focusing on an artificial neural network model applied to the mnist dataset and various penalty functions corresponding to a symmetric matrix game. The rationale behind memorization is elucidated, alongside potential avenues for future research. The results of the experiments validate the efficiency of the proposed approach. Notably, our solution for symmetric matrix games surpasses alternative methods in terms of speed. Even in the context of multi-layer neural networks, a significant acceleration is observed in computing function values along fixed rays.

Keywords: L-BFGS · Lcg · Memoization · Directional derivative · Symmetric matrix game · Two-layer neural network · Mnint

Multi-Condition Multi-Objective Airfoil Shape Optimisation using Deep Reinforcement Learning Compared to Genetic Algorithms

Dasun Shalila Balasooriya, Alan Blair, Craig Wheeler and Stephan Chalup

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This study investigates the potential of Deep Reinforcement Learning (DRL) in the context of Multi-Condition Multi-Objective airfoil shape optimisation by benchmarking a customised DRL algorithm, namely Single-Step Proximal Policy Optimisation, against NSGA-II, a conventional genetic algorithm. We illustrate the capability of the DRL algorithm to effectively optimise across a continuous multi-condition plane, eliminating the need to discretise it into discrete points, a practice commonly employed in conventional Genetic Algorithms. We further demonstrate that the DRL algorithm achieves hypervolume averages and convergence rates that are competitive when compared to NSGA-II. Analysis of Deep Neural Networks extracted from the training phase of the DRL algorithm indicates that almost complete knowledge of the Pareto front is retained by the network, which can be utilised to accelerate the discovery of the Pareto front in similar optimisation tasks via transfer learning.

Keywords: Multi-objective optimization · Multi-condition multi-objective optimization · Deep reinforcement learning · Genetic algorithms · Airfoil

Evolutionary Optimization for Inverse Problem in Engineering: The Case Study of Defects Shape Reconstruction

Gleb V. Solovev, Alexander Hvatov, Oleg Petrov, Anna V. Kalyuzhnaya, Alexandra Klimova and Nikolay O. Nikitin

ITMO University, Saint Petersburg, Russia

Complex mechanical engineering problems usually have the following stages: problem formulation, conceptual design, embodiment development, detailed design, testing, manufacturing, and quality control. The many tasks in the quality control phase often require significant time commitments of highly skilled personnel to complete successfully. Therefore, the application of evolutionary optimization at this stage of production can reduce the engineer's involvement in the development process, thereby reducing the time and cost of the task. This paper explores the possibility of evolutionary algorithms to solve the inverse problem of flaw detection, specifically the reconstruction of defect shapes in a product. The proposed solution addresses one of themost challenging technical problems in flaw detection. Experimental studies on a synthetic example demonstrate that the proposed approach can provide a qualitative reconstruction of various defect shapes, even with a limited number of sound pressure receivers. The results show that sound pressure measurements at 64 points are sufficient to correctly detect a defect located anywhere in space and fully recover its shape. Thus, using the defect shape reconstruction problem, the study confirms that evolutionary algorithms can be applied to various engineering problems.

Keywords: Evolutionary optimization · Engineering · Acoustics

Scheduling of Satellite Constellation Operations in EO Missions using Quantum Optimization

Vinicius Marchioli, Mattia Boggio, Deborah Volpe, Luca Massotti and Carlo Novara

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As Earth Observation (EO) missions advance towards Agile Earth Observation Satellites, the complexity of scheduling problems increases, posing challenges for traditional optimization methods. This paper investigates the potential of a quantum algorithm to address the scheduling problem in EO constellations. In particular, a novel formulation of the satellite constellation optimization problem is proposed, translating it into a Quadratic Unconstrained Binary Optimization (QUBO) problem, i.e., compliant with quantum solvers. Penalty functions are incorporated to optimize mission energy consumption. The formulated QUBO problem is then implemented and solved on a real quantum computer (a D-Wave Quantum Annealer). The performance provided by the quantum machine is compared with established classical meta-heuristic solvers like Simulated Annealing and Tabu Search. The results show that the proposed quantum optimization process achieves better results in terms of both solution quality and computational efficiency.

Keywords: Quantum optimization · QUBO · Earth observation mission · Satellite constellation scheduling

Learning Algorithms for Breast Cancer Classification and Diagnosis

Ana Beatriz Miranda Valentin, Glaucia Maria Bressan, Elisângela Ap. da Silva Lizzi and Fabrício Martins Lopes

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The comprehension about the key features of breast tumors that lead to their classification as benign or malignant is fundamental to improvie the detection and diagnosis of breast cancer, contributing significantly to survival rates and treatment effectiveness. This study proposes a multidisciplinary approach that combines analytical methods and graphical visualizations to classify breast tumors as benign or malignant, using supervised and unsupervised learning algorithms. The adopted dataset in this study is from the repository of the University of Wisconsin (USA). It comprises 569 breast tumor biopsy samples, with 32 features measured from digitized images of biopsy slides. Initially, for unsupervised learning, Pearson correlation was used as a similarity metric for hierarchical grouping, resulting in the formation of six clusters through a dendrogram. In supervised learning, the Principal Component Analysis (PCA) technique was performed to reduce the number of features, achieving the 10 most relevant. The Support Vector Machine (SVM) model was applied with and without the PCA results. The comparison between hierarchical grouping and SVM methods demonstrated a notable advantage of SVM in terms of accuracy in classifying breast tumors. The use of cross-validation showed the superiority of SVM over clustering for this specific purpose. The analysis of breast tumor features and the classification approaches offer important perspectives on improving breast cancer diagnosis and treatment practices. The use of classifiers such as SVM, together with dimensionality reduction techniques such as PCA, can result in significant improvements in diagnostic accuracy and effectiveness, directly benefiting patient care in this critical area of medicine.

Keywords: Breast cancer · Tumor classification · Feature selection · Efficient diagnosis

Enhancing Quadruped Robot Performance through Gait Optimization

Gustavo Cohen, José Lima and Paulo Costa

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Quadruped robots hold immense potential for navigating in unknown environments due to their ability to use individual footholds as well as their increased stability in uneven terrain. However, legged robots often experience limitations due to weight shifts during gait transitions.These weight shifts can cause torque peaks that exceed the capacity of the joint motors (overdrive torque), which lead to an increased risk of mechanical failure. Through the optimization of gait parameters, it is possible to reduce these risks while maximizing performance. This paper presents the use of multi-objective optimization algorithms for gait optimization in a simulated quadruped mammal robot within the Pybullet physics engine. The main focus of the study was to compare the performance of NSGA-II, NSGA-III and U-NSGA-III in minimizing overdrive torque while maximizing travel distance. The results showed that the three algorithms solve this problem, although the NSGA-III consistently yields better results in comparison to the other versions of the NSGA algorithm.

Keywords: Legged robot · Multi-objective optimization · Simulation

P-fuzzy System Applied to Population Dynamics: A Case Study

Elenice Weber Stiegelmeier and Glaucia Maria Bressan

Universidade Tecnológica Federal do Paraná

The objective of this paper is to propose a Fuzzy Rule-Based Systems for elucidating the management of weed population dynamics, primarily from a theoretical stand point. The input factor pertains to the categorization of weed populations into six discrete classes, namely: low, medium low, medium, medium high, high, very high. The resultant output corresponds to the rate of population variation, also discretized into four classes: low-negative, low-positive, medium-positive, high-positive. To regulate the weed population, we introduce a fuzzy control model, which is coupled to the partial p-fuzzy population model. The numerical results visually represent the progression of weed populations and our analysis leads us to the conclusion that the proposed p-fuzzy model demonstrates favorable results when compared to the weed dynamics model

Keywords: Population dynamics · Fuzzy modeling · Weed control

Covariance Control of an Earth-to-Mars Transfer with Control Actuation Errors

Boris Benedikter and Alessandro Zavoli

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This paper presents a convex optimization approach to design a covariance control policy for an interplanetary mission of a spacecraft subject to non-Gaussian control actuation errors. The goal is to develop a closed-loop policy that minimizes the control effort and ensures that the system's final state aligns with a desired probability distribution.This is achieved by formulating an optimal covariance control problem, which is then transformed into a sequence of deterministic convex optimization problems using state-of-the-art convexification techniques.Two noise models are devised to conveniently incorporate the perturbations in an optimal control framework with low computational complexity. The first is a (conservative) additive white Gaussian noise model, while the second is a more advanced multiplicative noise model, better suited to capture the system's noise characteristics.

Keywords: Stochastic optimal control · Covariance control · Convex optimization · Trajectory optimization

Assessment of Logistics Performance Indicators in Southern European Countries Optimizing the Decision Making

Bruna Barros, Helena Sofia Rodrigues and Ângela Silva

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The Logistics Performance Index (LPI) comprises a set of logistic indicators facilitating global analysis of logistic performance, serving as a vital analytical tool for economic integration and sustainable development across nations. These indicators encompass customs processes, infrastructure, international shipments, quality of logistic services, tracking and tracing capabilities, and timeliness. This tool plays a pivotal role on a global scale, being indispensable for the seamless operation of supply chains and fostering economic integration and sustainable development. In an increasingly interconnected world, logistic efficiency is imperative for trade facilitation and economic expansion. This study delves into the performance of Southern European countries concerning logistic challenges, employing multi-criteria decision models to ascertain the maximum score for each logistic indicator. Spain and Cyprus are highlighted as exemplifying the strengths and weaknesses of this European region, emphasizing the need for enhanced cooperation to attain more sustainable growth.

Keywords: Logistics performance indicators · CRITIC method · Best worst method · SAW method · MARCOS method

Enhancing Thermal Fiducial Marker Detection: Focus on Image Processing Techniques

Andre França, Guido S. Berger, André Mendes and José Lima

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This article proposes methods for maximising the detection rates of thermal fiducial markers using thermography. By exploring the combination of image processing techniques with the use of an affordable thermographic camera, the aim is to mitigate the negative effects of thermography and improve accurate marker identification in a variety of mounting and distance conditions. The research identified a diversity of processing techniques capable of improving thermal marker recognition, offering the potential to surpass previous results. The results highlight the possibility of using low-cost thermographic cameras for this purpose, which could democratise and reduce the costs of recognition processes. This methodology validates the proposed approach, providing a robust basis for future improvements in thermal marker detection and promoting the feasibility of practical, low-cost applications in an assortment of fields.

Keywords: Thermal · Fiducial markers · Image processing · Processing techniques

Enhancing K-way Circuit Partitioning: A Deep Reinforcement Learning Methodology

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Multiway circuit partitioning is a key combinatorial optimization problem thatappears many times throughout the Very Large Scale Integration (VLSI) design workflow. However, as VLSI designs continue to grow in size and complexity in accordance with Moore's law, current circuit-partitioning algorithms, which are mostly based on simple heuristics that become easily trapped in local minima,are increasingly hard-pressed to produce high-quality solutions in reasonable amounts of CPU runtime. To address this challenge, this paper proposes a novel circuit-partitioning algorithm that combines Deep Reinforcement Learning (DRL) with the popular Fiduccia-Mattheyses-Sanchis (FMS) circuit-partitioning heuristic. A perturbation function that enables random moves is first added to FMS. Then, a DRL agent is trained to dynamically apply the perturbation function during the search in order to enable FMS escape local minima and to accelerate convergence towards higher-quality solutions. The experimental results obtained by the proposed approach show significant improvements both in solution quality and CPU runtime.

Keywords: Circuit partitioning · VLSI · Deep reinforcement learning

Forecasting Blood Donation: A Machine Learning Exploration

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According to the National Estimation of Blood Requirement in India 2018 [1], 26.4 million whole blood units must be collected for the nation to meet its needs for whole blood and its constituent parts. Similarly, the PIB report revealed that a demand for blood transfusions arises every two seconds in India and every year, 14.6 million units of blood are required, with a 1-million shortage. Every day, over 38,000 people need to donate blood. Universities and institutes are ideal places for blood donations due to their young, enthusiastic volunteers. However, blood donation camps often receive lower-quality donations compared to hospitals requirement. Various psychological, social, and environmental factors can influence people's unwillingness to donate blood. To address this issue, our study is investigating advance ML techniques to forecast blood donation intent during blood drives or medical emergencies. The study collected dataset using an online questionnaire survey with informational, behavioral, and psychometric questions from voluntary university students. The results show that Deep Neural Network has the highest accuracy at 99.32%, followed by K-Means at 98.6%, and Support Vector Machine at 98.4%. The study successfully compared all popular classification algorithms and aims to deliver a technological solution to the problem.

Keywords: Machine learning · Blood donation · Prediction algorithms · Classifier · Supervised · Unsupervised

Computer Vision for Detecting Attentional Behaviors

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In the present day, we encounter the paradox of technology: although smartphones have revolutionized our way of living, bringing convenience and connectivity, they have also introduced new challenges, notably distracted driving. This work delves into the issue of visual distraction, one of the main contributors to traffic accidents, through the development of an innovative system that combines the application of convolutional neural networks and the functionality of mobile devices. The adopted methodology focused on the collection of a broad set of images to train an artificial intelligence model capable of classifying a qualitative variable with two distinct categories: attention and distraction of a driver. In particular, the study concentrated on creating a mobile application that uses a smartphone's camera to monitor the driver and issue auditory alerts if it detects prolonged distraction. The results achieved highlighted the efficacy of the model, especially after its optimization for the TensorFlow Lite format, suitable for implementation on mobile devices due to its efficiency in terms of speed and resource consumption, despite a reduction in prediction accuracy of 25.93% compared to the original TensorFlow model.

Keywords: Traffic safety · Convolutional neural networks · Mobile applications · Distraction detection

Cochineal Colony Detection in Cactus Pear: A Deep Learning Approach

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Object detection is a fundamental task in computer vision, playing a crucial role in various applications such as surveillance, autonomous driving, and agriculture. In agricultural contexts, object detection techniques are essential for assessing plant health and implementing targeted interventions. In this paper, we introduce a novel methodology for the detection of cochineal colonies of Dactylopius opuntiae incactus pear, which aims to estimate the degree of infestation and facilitate precise treatment strategies. Leveraging recent advancements indeep learning, we present a new dataset specifically curated for colony cochineal detection in cactus pear. We evaluate the performance of three state-of-the-art deep learning models, namely YOLOV7, YOLOV8, and YOLO-NAS, using our dataset. Through rigorous experimentation and comparative analysis, we identify YOLOV8 as the most effective model for colony cochineal detection in cactus pear. The proposed approach not only offers accurate colony detection but also provides valuable insights for implementing precise treatment measures, thereby contributing to the efficient management of plant infestations.

Keywords: Cactus pear · Object detection · Cochineal colony · Deep learning · YOLO

Optimizing Food Delivery Efficiency: The Impact of Order Aggregation and Courier Assignment Strategies

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The increasing demand for food delivery services necessitates optimizing courier efficiency to maintain service quality and cost-effectiveness. This study investigates the impact of order aggregation and courier assignment strategies on food delivery performance. We explore various order aggregation methods, including KMeans and DBSCAN clustering, and compare them with different courier assignment approaches, such as first-in-first-out and nearest courier selection. Through experiments on both synthetic and real-world data, we demonstrate that order aggregation, particularly when combined with the nearest courier approach, significantly reduces delivery times and courier travel distances, especially under high order volumes. Our findings provide valuable insights for food delivery platforms seeking to optimize their operations and enhance customer satisfaction.

Keywords: Real-time system · Online scheduling theory · Order aggregation · Courier assignment · Food delivery

Comparison Between Single and Multi-objective Clustering Algorithms: MathE Case Study

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This paper compares the results obtained for four single clustering algorithms with a multi-objective clustering approach. For this, a dataset describing the student's behavior within the Linear Algebra topic on the MathE e-learning platform is used. This dataset aids in understanding student performance and engagement in MathE to support the development of an intelligent system to tailor the platform's resources to users's needs. The four algorithms suggested two clusters as the optimal solution for the dataset. However, this binary categorization did not provide meaningful insights into the proposal of the MathE platform" that is, it did not provide a customized system according to individual needs. Thus, this study uses the multi-objective clustering algorithm, which results in a set of non-dominated solutions, providing decision-makers with a broader range of options to choose the solution that best meets their needs. The results demonstrate the main benefits of the proposed human-in-the-loop multi-objective approach since it provides several optimal solutions and allows the decision-maker to apply fundamental knowledge to define the most appropriate solution to the problem based on previous knowledge.

Keywords: Multi-objective clustering · Automatic clustering · Optimization · Bio-inspired algorithm

A Comparative Analysis of MATLAB and Python Neural Networks for Diabetes Prediction

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In recent years, artificial intelligence (AI) has become an integral part of many everyday applications. The growth of AI is bringing intellectual benefits to humans. It is revolutionizing discovery, learning, communication, and work. Machine learning, especially deep learning, is critical to this progress, providing complex models to process data more effectively. Neural networks, which emulate biological processes, find applications across diverse fields, notably in medicine, where they automate disease diagnosis and prediction tasks, such as diabetes. This paper proposes a comparative analysis between Python and MATLAB for diabetes prediction using a dataset with 100,000 individuals. The study conducts simulations on both platforms and validates the results using metrics such as precision, specificity, accuracy and F-measure. Additionally, the study emphasizes the importance of platform selection based on considerations of functionality and cost, offering insights into optimizing outcomes in healthcare applications.

Keywords: Neural network · Feed-forward in MATLAB and Python · MLP in MATLAB and Python · MATLAB · Python

Nelder-Mead Based Algorithms for Noisy Functions

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Optimization of noisy objective functions involves the process of searching for increasingly better solutions, perhaps the optimal one, while performing function evaluations that are influenced by some uncertainty. Different types of real-world problems fall into this category and, over time, several algorithms have been proposed to solve them efficiently. One of them is the recent Robust Parameter Searcher (RPS), which uses the Nelder Mead Simplex algorithm with some additional operators that perform multiple evaluations of a tentative solution and compare solutions based on a statistical test. This work further explores some possibilities of new operators, and carries out a computational experiment to analyse the effectiveness of different algorithm versions. The experimental results indicate that the RPS version whose single solution reevaluation limit grows non-linearly and whose comparison operator is based on statistical testing was efficient as a good alternative in dealing with noisy optimization problems with real variables and box-type constraints.

Keywords: Noisy optimization · Robust parameter searcher · Nelder Mead simplex · Uncertainty

Optimizing Waste Collection in Constrained Urban Spaces: A Hybrid Fleet Approach

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The automotive industry is witnessing a surge in the production of electric vehicles (EVs) driven by stringent emission regulations. Despite this growth, heavy-duty truck fleets, particularly in waste collection, remain predominantly combustion-based ones. Waste collection is critical in urban environments, presenting unique challenges due to confined operational regions. One alternative to increase EVs in waste collection is to substitute the smaller truck fleets used for waste collection in constrained environments, such as narrow streets, by EVs. In this paper, we present a new formulation for the waste collection problem that considers a truck fleet comprised of smaller EVs and regular combustion trucks. The smaller trucks are proposed for the waste collection of specific sites (i.e. dumpsters in narrow streets). Our formulation considers battery limitations of electric trucks and flexible time windows for the waste collection task. The solution was validated by comparing the emission of CO2 and collection costs of a fleet comprised solely of combustion trucks and the hybrid fleet proposed here. The results showed that using a hybrid fleet significantly reduced waste collection costs and environmental impacts.

Keywords: Electric vehicle · Waste collection · Fleet

Colorectal Polyp Segmentation: Impact of Combining Different Datasets on Deep Learning Model Performance

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Colorectal cancer is a major health concern, ranking as one of the most common and deadly forms of cancer. It typically begins as polyps, which are abnormal growths in the intestinal mucosa. Identifying and removing these polyps through colonoscopy is a crucial preventative measure. However, even experienced professionals can overlook some polyps during examinations. In this context, segmentation algorithms can assist medical professionals by identifying areas in an image that correspond to a polyp. These algorithms, which rely on deep learning, require extensive image datasets to effectively learn how to identify and segment polyps. This study aimed to identify public colonoscopy image datasets that contain polyps and to examine how combining these datasets might affect the performance of a deep learning-based segmentation algorithm. After selecting the datasets and defining their combinations, we trained a segmentation algorithm on each combination. The evaluation of the trained models showed that merging datasets can enhance model generalization, with increases of up to 0.242 in the dice coefficient and 0.256 in the Intersection over Union (IoU). These improvements could lead to higher diagnostic accuracy in clinical settings, enhancing efforts to prevent colorectal cancer.

Keywords: YOLO · Generalization · Datasets merging

Districting in Last Mile Delivery: Route Creation Using SHPP-based Algorithms

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Districting can reduce the complexities of delivery problems by segmenting its dimensions while facilitating drivers' familiarity with their work areas, fostering personal connections with customers, and enhancing satisfaction. This paper introduces and evaluates multiple heuristic approaches for route creation, aiming to identify the most efficient method for itra-district routing. Out of 18 tested variants, the best-performing developed approach used a Lin-Khernigan-based heuristic, later converting it to a Shortest Hamiltonian Path in each district, creating inter-district connections to a hypothetical centroid in the next district to visit and utilizing asymmetric road distances. The results obtained are satisfactory, and a summary of a new future model was proposed to reduce the number of necessary drivers, and consequently traveled distances and service times. The models were developed and tested using real-world data from a parcel delivery company operating in the Porto metropolitan area, in Portugal.

Keywords: Districting · Last-mile delivery · Shortest hamiltonian path problem

A Neural Network-based Approach to Identifying Wrinkles and Recommending Cosmetic Products

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Skincare has become a constant demand among the population, who are increasingly concerned about their health. Furthermore, environmental issues arouse the interest of the masses in natural and sustainable products. This project proposes an approach for recommending thermal-based products based on a set of information provided by the user, combined with the results of computer vision algorithms (to identify the age and occurrence of wrinkles on the user's forehead). A list of recommended products is generated based on the profile determined for the user. To predict wrinkles, for each facial image sent by the user, we apply a pre-processing step that segments and prepares the region of interest, which a CNN will process. As a CNN, we used the VGG16 architecture trained using a transfer learning and fine-tuning strategy, which improved the results obtained, reaching an accuracy of 92% in classifying wrinkles. An algorithm provided by the Deepface tool is used to predict the user's age, based on the sent picture, which is crossed with the user's information to determine a level of aging in order to improve the quality of the the recommended products.

Keywords: Deep learning · Wrinkle detection · Recommendation system · Skin care

Augmented Reality in Industrial Training: A Comparative Analysis of Teaching Methods

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This paper presents a comparative analysis of three distinct training methods-Augmented Reality, Guided Instruction, and Self-Directed Instruction-within an industrial setting, specifically a car manufacturing plant. The study assesses the efficacy of these methods across several metrics including learning efficiency, user satisfaction, and skill retention. The research highlights how Augmented Reality (AR) can enhance the training process by reducing time to competency, improving engagement, and fostering a deeper understanding of complex tasks. The findings indicate that AR, despite its initial learning curve, can outperform traditional methods in several key areas, notably in reducing the time required for training and enhancing participant motivation. The study also explores the emotional responses of participants, providing insights into the user experience associated with each training method. This paper argues for the broader adoption of AR in training modules, suggesting that AR technology can lead to more efficient, engaging, and effective training solutions, thus supporting the ongoing transformation towards Industry 4.0.

Keywords: Learning theory · Augmented reality · Education

Optimization of Machine Learning Models Applied to Robot Localization in the RobotAtFactory 4.0 Competition

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Several approaches have been developed over time aiming to improve the localization aspects, especially in mobile robotics. Besides the more traditional techniques, mainly based on analytical models, Artificial Intelligence has emerged as an interesting alternative. The current study proposes to explore the machine learning parameters optimization for pose estimation, using the RobotAtFactory 4.0 competition as the main context. Using a Bayesian Optimization-based framework, the parameters of a Multi-Layer Perceptron (MLP) model trained to estimate the components of the 2D pose (x, y, and θ) of the robot were optimized in four different scenarios of the same context. The results obtained showed a quality improvement of up to 77% on the estimation when compared with the modes without any optimization. Another aspect observed was the different optimizations found for each model, even in the same scenario. Also, another interesting result was the possibility of the reuse of optimization between scenarios, presenting an interesting approach to save time and computational resources, and still obtaining a useful optimization.

Keywords: Localization · Machine learning optimization · Robotics

Optimizing Facility Location for Insect Production

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Food waste poses a significant challenge to the sustainability of traditional food production systems, prompting global efforts to combat waste throughout the supply chain. Sustainable food production emerges as a critical concept in response to increasing concerns aboutenvironmental degradation and the need for alternative protein sources driven by global population growth. In this context, insect production offers a promising solution by converting low-value organic waste into nutrient-rich products, thus reducing waste and environmental impact. This paper addresses the urgent need for sustainable and efficient food production systems by introducing a facility location problem within the network design of insect production. The objective is to develop methods to scale insect-derived product production by identifying optimal locations with the best conditions for establishing insect production facilities. Emphasis is placed on connecting suppliers with production, highlighting the critical role suppliers and their by-products play in promoting a sustainable industry.Instances were generated to assess model performance, including supplier and facility locations, by-product availability and selection. Varying by-product availability yielded different optimization outcomes. The experiments results offered insights into the model's behavior under different conditions. The results shown that varying the composition of substrate had a major implication on the augment of costs compared to varying the by-product availability.

Keywords: Sustainable food production · Food waste · Insect production · Facility location problem

Allocation and Sequencing of Missions on Autonomous Vehicles

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Pickup and delivery problems are frequently encountered problems in transport companies. This paper presents a variant of the homogeneous vehicle, single-to-single Pickup and Delivery Problem with Time Windows, where several vehicles must fulfill transport requests from pickup nodes to delivery nodes, called missions, with associated service level agreements (SLA). This variant focuses on optimizing the allocation and sequencing of missions to be executed by autonomous vehicles. Firstly, the mathematical programming model is formally defined, highlighting the characteristics of the problem addressed. Once the mathematical programming has been defined, the migration to the computational model takes place. The model is subject to a comparative test on the basis of two available datasets that are presented and analyzed in the article. The results show that the model is capable of finding plausible, high quality solutions that respect the constraints, giving the sequence of missions assigned to each vehicle and their respective start and delays times.

Keywords: Pickup and delivery problem · Optimization · SLA

Clustering Algorithm to Improve Local Search's Performance for a Public Bicycle Sharing System

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The Bicycle Sharing Systems (BSS) have emerged as a sustainable and convenient mode of urban transportation, providing an alternative to traditional commuting methods. Despite its benefits, BSS'sefficient management and optimization face inherent challenges, ranging from system demand variations to station capacity constraints. This paper addresses a tactical problem in BSS, namely the districting problem. The districting BSS problem aims to find a network configuration where the stations are allocated to cluster centres so that each cluster meets balance constraints. The problem is modelled as an integer programming problem. In a previous work [4], we implemented a matheuristic based on a local search algorithm which selects the centre of each cluster of stations. Then, a mathematical solver solves the allocation of the stations to the centres, considering balancing constraints. In that paper, we limited our local search to choose a cluster centre within predefined clusters to reduce the search space. This paper investigates the effect of the clustering strategy on the local search's performance. Thus, this paper implements a clustering strategy to provide the local search algorithm with better clusters or grids. We try the well-known k-means algorithm to provide our local search matheuristic algorithm with different grids to seek on. The obtained results significantly improve the algorithms' performance compared to the arbitrary pre-defined grid used in our previous work. Also, results show that some grid designs tend to be better than others and, thus, impact the final results.

Keywords: Repositioning zone · Bicycle sharing system · Variable neighbourhood search · Clustering · Mathematical programming.

Optimisation of the Dynamic Waste Collection

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The aim of this work is to show how to optimise waste collection (WC) services in the context of the use of the Internet of Things (IoT). It is a challenge compared to traditional approaches which use fixed route planning and imply an unnecessary use of resources by including containers whose fill level does not require emptying on the routes. As part of a Smart Tourism Destination project, Adeje Municipality (Tenerife Island) has chosen to implement IoT smart sensors in waste bins to help address these challenges. The present study proposes the application of the Greedy Randomised Adaptive Search Procedure (GRASP) metaheuristic for dynamic route planning from real-time data. The origin-destination time and distance matrices are obtained using Geographic Information Systems (GIS). We use a Capacitated Team Orienteering Problem (CTOP) model that maximises the filling of collected containers to select the routes. The solutions to the problems are sets of routes for the fleet of trucks that collect waste, taking into account the limitations of the capacity of the truck and the duration of the routes. In this way, overflows are avoided, thus reducing pollution which contributes to the better perception of citizens and tourists.

Keywords: Waste collection · Team orienteering problem · GRASP

Decision-Aid Applied to Rank Diverse Energy Storage Systems Technologies: A Methodology Using Information Fusion Concepts

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The demand for electricity from renewable sources is increasingly becoming a necessity. Climate change and self-purchasing power demand is a greater nominal power from the public grid. In this way, hybrid microgrid systems (HMGS) - a type of smart grid - have become an alternative to meet power demand. One of the pieces of equipment that has become more essential in these systems is the energy storage system (ESS). Defining which technology is most suitable for a given microgrid is a hard task. This work presents the study and application of fourteen ESSs for a specific industrial electrical dispatch scenario maintained by an HMGS connected to the public grid network. The proposed mathematical modeling is solved by a swarm-evolutionary algorithm. The optimized values of cost, losses, and renewable factors are used as decision-making criteria to rank the ESS using the TOPSIS multi-criteria decision method. The results show that ESSs based on Vanadium Redox Flow can be a good alternative to recent Lithium-based technologies.

Keywords: Electric dDispatch · Smart grids · Swarm evolutionary algorithms

The Infodemic Issue: Numerical Modelling

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In today's digital age, the propagation of fake news has become a significant societal challenge. This article explores the application of epidemiological models to understand and model the spread of misinformation. Specifically, we present a case study involving a real incident of fake news, related to an earthquake, on the social media platform X (former twitter).The epidemic-like spread of this fake news was analyzed using the SIR (Susceptible-Infectious-Recovered) model. By fitting the SIR model to real data, optimal parameters governing the spread of the fake news were identified. Additionally, a control measure was simulated to evaluate its impact on mitigating the dissemination of the misinformation. This study underscores the utility of epidemiological frameworks in comprehending and fighting the viral propagation of fake news in an increasingly digital era.

Keywords: Fake news · Viral propagation · SIR model

Temperature Control of a Custom-made Soldering Station Using CDM

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This paper explores the applicability of the coefficient diagram method to design a soldering iron temperature controller. Soldering processes require precise control over temperature to ensure optimal solder joint quality and prevent damage to electronic components. Traditional PID controller design methods are less systematic than CDM which only require a minimum input from the user focusing on the relationships between the system's coefficients and performance criteria. By resorting to this method, an alternative temperature controller for soldering iron tips is developed, taking into account the thermal dynamics of the soldering process, including heat transfer characteristics, thermal inertia, and environmental factors. The effectiveness of the proposed temperature controller design is evaluated through experimental validation.

Keywords: Control systems design · Coefficient diagram method · Soldering station · Temperature control

Utility Function for Assessing the Cost of Recovering from Ransomware Attacks

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Nowadays, ransomware attacks have become one of the main problems organizations face. The threat of ransomware attacks, with their capacity to paralyze entire organizations, creates the need to develop a ransomware recovery utility function to help further prepare for the impact of such attacks and enhance the organization's knowledge and perception of risk. This work proposes a ransomware recovery utility function that aims to estimate the impact of a ransomware attack measured in manpower hours till recovery and taking into account different devices and different scenarios.

Keywords: Ransomware · Utility function · Costs · Recovery

Predicting Retail Store Transaction Patterns: A Comparison of ARIMA and Machine Learning Models

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Transactions in the retail sector represent sales of consumer goods, or final goods, by consumer companies. The sales rush can affect employee safety by increasing workload, straining resources, and creating potential workplace hazards. Although this sector presents a lower risk of injury or death than other activities, employees perform various challenging tasks and are exposed to multiple hazards. Therefore, it was essential to know the number of customers waiting in the store daily, as it would allow companies to dynamically adjust staffing schedules, aligning workforce capacity with expected demand levels. This is possible by predicting transactions using past observations and forecasting algorithms. Therefore, this study aims to compare the ARIMA time series algorithm and several Machine Learning algorithms to find the best approach to predict the number of daily transactions for each store pattern, considering the transaction level and data variability. Using daily transactions from a Portuguese chain stores between 2019 and 2023, this study selects four typical store patterns based on transaction levels and data variability. Through the difference in variability in the store and the results obtained, the best algorithm that obtains the smallest errors for predicting daily transactions for each store was chosen. This study aims to contribute to the existing gap in forecasting daily customer transactions and to implement a suitable forecasting model to mitigate risks associated with varying patterns of in-store sales flow.

Keywords: Forecasting · Transactions · Time series · Machine learning

Facial Expression Recognition in Virtual Reality Simulations

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Facial expressions are an important channel for interpersonal communication and comprehension, since people externalize their emotions through a variety of facial expressions. Technology, in particular, deep learning algorithms, can detect and analyze human emotions in real time, which paves the way for advanced user interfaces or adjustable devices and applications. Based on this, the work described in this paper presents a system that identifies three groups of emotions, positive, negative, and neutral, for adjusting user experience in Virtual Reality (VR) games. This, however, introduces an additional challenge in classifying expressions, because of the partial occlusion of the face. To solve this problem, four CNNs were used: VGG-19, ResNet-18, EfficientNet-b1, and Mini-Xception, as well as the ensemble of the three most accurate models (VGG-19, EfficientNet-b1, ResNet-18) via max voting. As expected, this ensemble, which we designate as VERNet, was the most accurate model, with an accuracy of 85.7% without partial occlusion of the face and 82.7% with occlusion. When compared with the accuracy of VGG-19, the results of VERNet only differ by 1% when compared with VGG-19. The minor difference between the results with and without occlusion demonstrated that an outside camera can be a very robust solution for tracking human facial expressions in VR environments.

Keywords: Facial expression recognition · Partial occlusion · CNN · Emotion detection · Serious games · Virtual reality

A Multi-objective Approach for Solving Distributed Job Shop Scheduling Problems

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Nowadays, the industrial market is characterised by high levels of competition, with customers increasingly demanding in terms of quality, delivery times, costs, etc. However, with increasing demand and the need to increase productivity, many companies in recent years have dedicated themselves to decentralising their factories, thus moving to distributed production. Today's manufacturing systems are distributed in the sense that there are several jobs that have to be carry out on machines located in different factories. This paper proposes a multi-objective distributed job shop scheduling model with unrelated parallel machines and sequence-dependent setup times. The transport time of raw materials to carry out a given job to a factory is also taken into account. Small instances of the problem were solved using NSGA-III with the aim of simultaneously minimising two objectives: the makespan and average completion time. Preliminary results show the validity of this approach.

Keywords: Distributed job shop scheduling problem · Multi-objective optimization · Evolutionary algorithms.

Optimizing Olive Disease Classification Through Hybrid Machine Learning and Deep Learning Techniques

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Olive trees play a crucial role in the global agricultural landscape, serving as a primary source of olive oil production. However, olive trees are susceptible to several diseases, which can significantly impact yield and quality. This study addresses the challenge of improving the diagnosis of diseases in olive trees, specifically focusing on aculus olearius and Olive Peacock Spot diseases. Using a novel hybrid approach that combines deep learning and machine learning methodologies, the authors aimed to optimize disease classification accuracy by analyzing images of olive leaves. The presented methodology integrates Local Binary Patterns (LBP) and an adapted ResNet50 model for feature extraction, followed by classification through optimized machine learning models, including Stochastic Gradient Descent (SGD), Support Vector Machine (SVM), and Random Forest (RF). The results demonstrated that the hybrid model achieved a groundbreaking accuracy of 99.11%, outperforming existing models. This advancement underscores the potential of integrated technological approaches in agricultural disease management and sets a new benchmark for the early and accurate detection of foliar diseases.

Keywords: Optimization · Hybrid model · Machine learning · Deep learning · Olive disease · Olive leaves

Route Optimization for Urban Last-Mile Delivery: Truck vs. Drone Performance

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In urban environments, last-mile item delivery relies heavily on trucks, causing issues like noise pollution and traffic congestion. Unmanned Aerial Vehicles (UAVs) offer a promising solution to these challenges. This study compares the effectiveness of delivery using trucks versus drones. Two customer datasets, one clustered and one random, were used for testing. Route optimization involved four deterministic and four non-deterministic algorithms. The performance of these algorithms, considering the total distance traveled, was evaluated across different datasets and vehicle types. The top two algorithms were further assessed for environmental impact and cost efficiency. Battery consumption along the routes was also analyzed to gauge operational feasibility.

Keywords: Vehicle routing problem · UAVs · Guided local search

Modeling and Cost Optimization for M/M/1/K Queue With Dual-phase Service and Repair Under Threshold Recovery

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NIT Surat

In this paper, we investigate an M/M/1/K queue with dual-phase service and repair under threshold recovery. This system is characterized by a single server that provides customers with two consecutive phases of service. Furthermore, the system may experience the unpredictability of sudden server breakdowns, necessitating repair. A dual-phase repair process is implemented to address server failures, but repair begins only when the number of customers in the system reaches a certain threshold value of Q ($1 \leq Q \leq K$). To thoroughly understand the system, we mathematically construct steady-state equations for the model and then use a recursive method to solve them, thereby yielding steady-state probabilities. We also derive several performance measures, with the primary objective of decision-makers being to maximize profit while minimizing the inconvenience caused by service delays for customers. In pursuit of this goal, we construct a cost function that incorporates the threshold parameter and the service rate as decision variables and define an optimization problem with the aim of attaining the optimal cost. A population-based particle swarm optimization (PSO) is implemented to minimize the cost by identifying the optimal threshold parameter and service rate. After developing a model, the objective of the study is twofold: firstly, to conduct a thorough analysis of system performance using measures such as system size and waiting time, providing decision-makers with valuable insights into operational efficiencyand customer satisfaction levels, secondly, the study aims to minimize the cost function by using PSO, thereby optimizing operational processes to achieve the most cost-effective solution while maintaining high service quality.

Keywords: Finite queue · Dual-phase service · Server breakdown · Dual-phase repair · Threshold recovery · Cost optimization · PSO

An N-Queens Benchmark Using MILP Solvers - Comparison Between Open-Source Optimization Tools

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In line with the Recovery and Resilience Plan, the New Generation Storage (NGS) project aims to establish a sustainable technological value chain. Its main objective is the sustainable manufacture and recovery of batteries for electric mobility. Thus, it was decided to evaluate three open-source optimization tools to identify their strengths and weaknesses, aiming to select the most robust optimization service for the project. In this sense, this paper presents an exploratory study on three open-source optimization tools. The main goal was to assess their performance in solving optimization problems that can be applied to real-world scenarios, like the NGS project. The evaluations were conducted using an N-queens benchmark, applying mixed-integer linear programming (MILP) modeling to validate the computational accuracy of each tool. Moreover, this study compares the performance, scalability, and computational efficiency of these tools to identify the most robust option for optimizing large-scale energy storage systems. The findings not only contribute to the selection of an optimal solver for the NGS project but also offer significant insights into the solver practical applicability in broader real-world scenarios, including industrial optimization and energy resource management.

Keywords: Open-source solver · Optimization · MILP · N-queens

XAI Framework for Fall Detection in an AAL System

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The Ambient Assisted Living (AAL) systems are human centered and designed to prioritize the needs of elderly individuals, providing them with assistance in case of emergencies or unexpected situations. These systems involve caregivers or selected individuals who can be alerted and provide the necessary help when needed. To ensure effective assistance, it is crucial for caregivers to understand the reasons behind alarm triggers and the nature of the danger. This is where an explainability module comes into play. In this paper, we introduce an explainability module that offers visual explanations for the fall detection module. Our framework involves generating anchor boxes using the K-means algorithm to optimize object detection and using YOLOv8 for image inference. Additionally, we employ two well-known XAI (Explainable Artificial Intelligence) algorithms, LIME (Local Interpretable Model) and Grad-CAM (Gradient-weighted Class Activation Mapping), to provide visual explanations.

Keywords: eXplainable AI · Ambient assisted living · Fall detection · Human-centered-systems · YOLO

Fuzzy c-means as a Decision Support Tool for Liver Disease Diagnosis based on Data Analysis

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The liver is a vital organ responsible for numerous essential functions in the body. Thus, liver disorders can have severe consequences on overall health and well-being. Early diagnosis and treatment of liver disorders are crucial to prevent complications such as cirrhosis, liver failure and liver cancer. In this work, a data analysis system aims to identify the most important features in defining liver disease and categorize sick patients according to the severity of the disease. The Indian Liver Patient Dataset was evaluated using a pre-processing data analysis method that considered the Z-score, the correlation, and the Recursive Feature Elimination. After identifying the most important characteristics of the patients, the Fuzzy c-means algorithm was used to classify them based on the severity of the disease. The results of the proposed methodology proved to be effective in creating a decision support system, since it was possible to identify four levels of severity among the patients.

Keywords: Decision support · Machine learning · Fuzzy clustering.

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