International Symposium on Applied Optimization and Game Theoretic Models for Decision Making

(ISOGTDM 2023)

Organized by

Indian Statistical Institute, Delhi Centre

Contents

Welcome to ISOGTDM 2023

On behalf of the organizers of ISOGTDM 2023, I welcome you all in the three days International Symposium on Applied Optimization and Game-Theoretic Models will be organized during February 1-3, 2023 at Indian Statistical Institute, Delhi Centre. This International symposium aims to promote research in the area of Applied Optimization and Game theory by bringing together world-leading experts and other specialists of the field along with young scholars.

This symposium will provide an excellent opportunity to disseminate the latest major achievements and to explore new directions and perspectives, and is expected to have a broad international appeal, dealing with topics of fundamental importance in applied optimization and other related sciences (Economics, Physics, Engineering).

This event mainly focuses on classical and modern optimization theory, algorithms (local and global aspects), stochastic optimization, structured optimization, reliability optimization, optimization methods in machine learning as well as related topics in applied mathematics, including game theory. This symposium also seeks for applied contributions on uncertainty modeling and optimization in the fields of logistics, manufacturing, and supply chain management where robust and/or stochastic models are used to provide decision support.

This symposium also intends to bring out a publication of selected and refereed papers in a special issue of Annals of Operations Research.

For details about this special issue visit

https://resource-cms.springernature.com/springer-cms/rest/v1/content/23684616/data/v1

Topics include (but not restricted to)

1. Linear and Nonlinear Programming
2. Multi-Objective Optimization
3. Global Optimization
4. Optimization Problem in Statistics
5. Network analysis and Optimization
6. Optimization Problems in Graph Theory
7. Nonsmooth Optimization
8. Neural Network algorithms for optimization problem
9. Combinatorial Optimization
10. Robust Optimization
11. Stochastic Optimization
12. New developments in Classical Combinatorial Optimization Problems (Knapsack, Vehicle Routing & Scheduling, Traveling salesman problem)
13. Game theory
14. Reliability optimization
15. Optimization techniques for game problems
16. Complementarity Problem and variational Inequalities
17. Application of Optimization Models to finance and Economics
18. Optimization Techniques in Machine Learning

Information about social events will be available to you at the time of registration.

S. K. Neogy
Organizing Committee Chair

Committees

Organizing Committee

S. K. Neogy (Chair), R.B. Bapat, Arunava Sen, Prabal Roy Chowdhury, K. Manjunatha Prasad.

Programme Co-ordinating Committee

R. B. Bapat, K. Manjunatha Prasad, Prabal Roy Chowdhury

Facilities Committee

P. Sreejith, Simmi Marwah, Praveen Pandey, Sajal Ghosh, Parama Gogoi and Srinivas

International Symposium on Applied Optimization and Game Theoretic Models for Decision Making

Program Overview

Inaugural Session Details

February 1, 2023 Time: 10:00 -10:45 Venue: Auditorium

Welcome address, Opening Remarks, About symposium,
Talk by Katta G. Murty (University of Michigan, Ann Arbor, USA) Sphere Method 7-6 Using No Matrix Inversions for Linear Programs (LPs)
Vote of Thanks

Tea Break: 10:45 -11:15

Sessions Details

February 1, 2023 Time: 11:30 -13:00 Venue: Auditorium

Invited Session I
Chairman : S. K. Neogy, Indian Statistical Institute, Delhi Centre

1.	**Juan Enrique Martinez-Legaz** (Universitat Autnoma de Barcelona, Spain) On the Gauss range of a closed convex set
2.	**S.K. Mishra** (Banaras Hindu University, Varanasi-221005, India) On nonsmooth V-invexity and vector variational-like inequalities in terms of quasidifferentials
3.	**Sandeep Juneja**, (Tata Institute of Fundamental Research, Mumbai, India) Sequential learning in a stochastic multi armed bandit framework

Lunch Break: 13:00 -14:00

February 1, 2023, Time: 14:00 -15:30 Venue: Auditorium

Invited Session II
Chairman: Agnieszka Wiszniewska-Matyszkiel, University of Warsaw, Poland

1.	**Reinoud Joosten**, Rogier Harmelink, Tom Sparrius, On optimality in contest theory models of long-run advertising and short-run competition, University of Twente, The Netherlands.
2	**Bo Chen** (The University of Warwick, UK) Sequential Jury Voting: A Median Voter Theorem and Beyond
3.	**S Dharmaraja** (Indian Institute of Technology Delhi) Study of infinite-server systems driven by Hawkes processes

Tea Break: 15:30 -15:45

February 1, 2023, Time: 15.45 -18:30 Venue: Auditorium

Technical Session-I A

Chairman : S.K. Mishra (Banaras Hindu University, Varanasi-221005, India)

1.	**R. Balaji (IIT Madras)** Moore-Penrose inverse of distance Laplacian matrices of trees are Z matrices
2.	Ruchika Seghal1**, Amita Sharma2**, Renata Mansini3 (NSUT, Dwarka) Worst-case analysis of Omega-VaR ratio optimization model
3.	**B. B. Upadhyay** (Indian Institute of Technology Patna) On Nonsmooth Interval-valued Multiobjective Programming Problems and Generalized Stampacchia Vector Variational Inequalities
4.	**Nagendra Singh**, Shahid Ali and Akhlad Iqbal (Aligarh Muslim University, India) Nonsmooth vector variational inequalities and Nonsmooth Vector optimization problems on Hadamard manifold
5.	Vivek Laha (Banaras Hindu University, Varanasi) On optimization problems using quasidifferentiability
6.	**Kuntal Som** (IIT Kanpur) SET-VALUED OPTIMIZATION PERSPECTIVE OF BILEVEL PROGRAMMING PROBLEMS
7	B.B. Upadhyay and **Priyanka Mishra** (Indian Institute of Technology Patna) Minty Variational Principle for Nonsmooth Interval-Valued Vector Optimization Problems
8	**Priyanka kalita**, Vidyottama Jain and S Dharmaraja Amity University, Central University of Rajasthan, Indian Institute of Technology Delhi, Hauz Khas, Delhi, 110016, India.Stochastic modeling of energy optimization in hybrid base station in 5G Networks
9	**Yogendra Pandey1** · S. K. Mishra2 (1 Satish Chandra College, Ballia 2, B.H.U, Varanasi) Optimality Conditions for Nonsmooth Optimization Problems with Switching Constraints in terms of Greenberg-Pierskalla Subdifferential
10.	**D Ghorui1*** S Sarkar2 , A Mallick2, A K Sribastava2, J De3 and G Majumdar2(1Ghani Khan Choudhury Institute of Engineering and Technology, 2Jadavpur University, Kolkata, India 3Academy of Technology, Hooghly, India) Optimization of the coating parameters of electroless Ni-Co-P coating using Artificial Bee Colony Algorithm

February 1, 2023, Time: 15.45 -18:30 Venue: Conference hall

Technical Session-I B

Chairman : S Dharmaraja (Indian Institute of Technology Delhi)

1.	**Shalu Yadav 1**, Amita Sharma 2 Ruchika Sehgal 3 1, 2,3 Netaji Subhas University of Technology(NSUT),New Delhi, Deviation Expectile-Mean Portfolio Optimization
2.	**Ishu Jain1** Anupam2 (Netaji Subhas University of Technology) Dependability Analysis of High Altitude Platform Station Using Stochastic Modeling Approach
3.	**Anupam** (Netaji Subhas University of Technology, Delhi-110078, India) A novel hierarchical model is proposed based on the architecture of LTE-A network.
4.	**Tamanna Yadav1** and S. K. Gupta1, (Indian Institute of Technology Roorkee, Roorkee), Optimality conditions and duality analysis for a class of conic semi-infinite optimization problem having vanishing constraints
5.	**Pooja Bansal (**NSUT Dwarka,New Delhi-110078, India) Sequential Malmquist-Luenbeger Productivity Index for Interval Data Envelopment Analysis
6.	**Kamyani Shukla1,** Ruchika Sehgal2 , Amita Sharma3 1, 3 Netaji Subhash University (NSUT) Delhi, 2Guru Gobind Singh Indraprastha University) Robust Linear Deviation Portfolio Optimization models and their Empirical Investigation.
7	**Nantu Kumar Bisui,** Geetanjali Panda (Indian Institute of Technology Kharagpur,) Trust region strategy for the nonconvex constrained multi-objective optimization problems
8	Shashi Kant Mishra, **Ravina Sharma** (Banaras Hindu University, Varanasi 221005, India.A Modified q-BFGS Algorithm for Unconstrained optimization)
9	**Asrifa Sultana** and Shivani Valecha (Indian Institute of Technology Bhilai, Chhattisgarh, India) Existence Theorems on Quasi-variational Inequalities over Banach Spaces and its Applications to Time-dependent Pure Exchange Economy
10	**Prachi SACHAN** and Vivek LAHA, (Banaras Hindu University, Varanasi, INDIA) On multiobjective optimization and vector variational inequalities using convexificators

February 1, 2023, Time: 15.45 -18:30 Venue: Seminar Room 1

Technical Session-I C

Chairman : Shanta Laishram, ISI Delhi Centre

1.	**Akriti Dwivedi*** and Vivek Laha, Banaras Hindu University) On interval-valued multiobjective semi-infinite programming
2.	Shashi Kant Mishra, **Jaya Bisht Banaras** Hindu University, Varanasi, India.) Hermite-Hadamard type inclusions for interval-valued coordinated Preinvex functions)
3.	Asrifa Sultana and **Shivani Valecha, (**Indian Institute of Technology Bhilai, Raipur - 492015, Chhattisgarh, India)A Class of Quasi-Variational Inequalities with Unbounded Constraint Maps: Existence Results and Applications
4.	S. K. Mishra and **Vandana Singh** (Institute of Science, Banaras Hindu University) Ostrowski type inequalities via some exponentially s-preinvex functions on time scales with applications
5.	Shashi Kant Mishra, **Soumya Rath,** Jaya Bisht (Institute of Science, Banaras Hindu University) Hermite-Hadamard-Jensen-Mercer type inequalities for strongly convex functions via Ψ-Riemann-Liouville k-fractional integrals
6.	S. K. Mishra and **Mohd Hassan(** Institute of Science, Banaras Hindu University,)Duality results for interval-valued semi-infinite optimization problems with equilibrium constraints using convexificator
7	**Sujeet Kumar Singh** (Indian Statistical Institute, Hyderabad, India) Unbiased scalarization technique for multi-objective fractional feed formulation problem
8	**Bharat Kumar** a,1 , Deepmala- a,2 and A.K. Das b,3 a PDPM-Indian Institute of Information Technology Design and Manufacturing, Jabalpur - 482005 (MP), India b Indian Statistical Institute, Kolkata-700108, India) More On Modulus Based Iterative Method For Solving Implicit Complementarity Problem
9	**Anveksha Moar** and C. S. Lalitha (University of Delhi,) A Derivative-free Descent Method for Solving Set Optimization using Oriented Distance Function
10	**Mridul Patel** · P. Kumar∗ (SRM Institute of Science and Technology Kattankulathur, Chennai-603203, India) Nonlinear enhanced interval fractional programming problem

February 2, 2023 Time: 10:00 -11:30 Venue: Auditorium

Invited Session III

Chairman: T. Parthasarathy, Chennai Mathematical Institute, Chennai, India

1.	**K.C. Sivakumar** (Indian Institute of Technology Madras, India) On an Analogue of a Property of Singular M-matrices, for the Lyapunov and the Stein Operators
2	**Tiru Arthanari** (The University of Auckland, New Zealand) A New Beginning in Computational Complexity of Combinatorial Optimisation problems • Why study Pedigree Polytopes?
3.	**Andreay Garnaev** (Rutgers University, North Brunswick, NJ 08901, USA) Prospect theoretical extensions of game-theoretical models in wireless communication.

Tea Break: 11:30 -11:45

February 2, 2023 Time: 11:45 -13:15 Venue: Auditorium

Invited Session IV

Chairman: T. Parthasarathy, Chennai Mathematical Institute, Chennai, India

1.	**Sanjeet Singh** (Indian Institute of Management Lucknow, India) Ranking of DMUs in a Peer Group Competitive Environment
2	**T. Parthasarathy** (Chennai Mathematical Institute, Chennai, India), Semimonotone matrices and completely mixed games
3.	**Lina Mallozzi** (University of Naples \Federico II", Italy) Approximation schemes for two-level optimization problems

Lunch Break: 13:15 -14:00

February 2, 2023 Time: 14:00 -15:30 Venue: Auditorium

Invited Session V

Chairman: C. S. Lalitha (University of Delhi)

1.	Rimpi, Aanchal and **C. S. Lalitha (University of Delhi)** Second-order Optimality Conditions for Geoffrion Proper Efficient Solutions in Nonsmooth Vector Optimization
2	**Vikas Vikram Singh** (Indian Institute of Technology Delhi, India) Stochastic Nash games under chance constraints
3.	**K. Manjunatha Prasad** (Manipal Academy of Higher Education, Manipal) Generalized Inverses in Network Optimization Problems

ISOGTDM23 Best Paper Award (Applications)

February 2, 2023 Time: 14:00 -14:40 Venue: Conference Hall

Technical Session-I A1

Chairman: K. Manjunatha Prasad (Manipal Academy of Higher Education, Manipal)

1.	**Rekha Yadav***, Santosh Singh* (Shiv Nadar University) and S. K. Neogy* (ISI, Delhi) From linear system of equations to artificial intelligence - The evolution journey of computer tomographic image reconstruction algorithms (to appear Applied Linear Algebra, Probability and Statistics - Series of SPRINGER, A volume in honor of C R Rao and A K Lal)
2	**Nishtha** 1 · Jolly Puri1 · Gautam Setia2 (Performance prediction of DMUs using integrated DEA-SVR approach with imprecise data: application on Indian banks

Tea Break: 15:30 -15:45

February 2, 2023, Time: 15.45 -18:30 Venue: Auditorium

ISOGTDM23 Best Paper Award (Methodology)

Technical Session-I A2
Coordinator : K. Manjunatha Prasad (Manipal Academy of Higher Education, Manipal)

1.	**ANSHUL PRAJAPATI** AND PUNIT SHARMA (Indian Institute of Technology Delhi) ESTIMATION OF STRUCTURED DISTANCES TO SINGULARITY FOR MATRIX PENCILS WITH SYMMETRY STRUCTURES: A LINEAR ALGEBRA--BASED APPROACH (SIAM J. MATRIX ANAL. APPL.2022 Vol. 43, No. 2, pp. 740—763)
2.	**Gambheer Singh a**,∗, S.K. Neogy b, Promila Kumar c (**a University of Delhi,** b Indian Statistical Institute, Delhi, c University of Delhi, A new subclass of Q0-matrix in linear complementarity theory (Linear Algebra and its Applications 647 (2022) 64–77)
3	Balendu Bhooshan Upadhyay1, **Arnav Ghosh**1, Priyanka Mishra1 and Savin Treant¸˘a2,3,* 1 Indian Institute of Technology Patna, 2University Politehnica of Bucharest, Romania.

	3 Academy of Romanian Scientists, Romania, OPTIMALITY CONDITIONS AND DUALITY FOR MULTIOBJECTIVE SEMI-INFINITE PROGRAMMING PROBLEMS ON HADAMARD MANIFOLDS USING GENERALIZED GEODESIC CONVEXITY (RAIRO-Oper. Res. 56 (2022) 2037–2065)
4.	**Bharat Pratap Chauhan**, Dipti Dubey, Shiv Nadar University, Dadri, India, On almost semimonotone matrices and the linear complementarity problem (Linear Algebra and its Applications 661 (2023) 35–50)
5	T. Parthasarathy1 · G. Ravindran2 · **Sunil Kumar2** 1 Chennai Mathematical Institute, 2 Indian Statistical Institute, Chennai, India, On Semimonotone Matrices, R0-Matrices and Q-Matrices (Journal of Optimization Theory and Applications (2022))
6	**Mohit Kumar Baghel1** Nicolas Gillis2 Punit Sharma1, (1Department of Mathematics, Indian Institute of Technology Delhi, 2University of Mons,Belgium,) Characterization of the dissipative mappings and their application to perturbations of dissipative-Hamiltonian systems, Numer Linear Algebra Appl. 2021;28:e2402.
7	**Rimpi** a and C. S. Lalitha b, (a University of Delhi; bUniversity of Delhi, Constraint qualifications in terms of convexificators for nonsmooth programming problems with mixed constraints OPTIMIZATION https://doi.org/10.1080/02331934.2022.2045987

February 2, 2023, Time: 15.45 -18:30 Venue: Conference hall

Technical Session-II A

Chairman : Sanjeet Singh, Indian Institute of Management Lucknow

1.	**Sanjeet Singh** a, and Prabhat Ranjanb (aDecision Sciences Area, Indian Institute of Management Lucknow) Cross efficiency approach for non-homogeneous parallel sub-units: A case of ranking in higher education
2.	**D K Mahalik** (Sambalpur University) **DEVELOPMING AN MODEL FOR ASSESSMENT OF SUBJECTIVE ANSWAR USING DATA ENVELOPMENT ANALYSIS**
3.	**Shrikant Singh** and Gopal Sharan Parashari (Institute of Technology Dharwad, Karnataka, India) Game Theoretic Model on Sharing Infrastructure Among Battery Swapping Stations
4.	**Radhika Kavra**, Anjana Gupta, Sangita Kansal (Delhi Technological University, Bawana Road, Rohini, Delhi, India.) New approaches of extending energy optimal topology on interval graph model of wireless sensor networks with sensitivity analysis
5.	**K. D. Lewis,** A. J. Shaiju (Indian Institute of Technology Madras) On the invariance of profiles and convergence of replicator trajectories in quadratic games
6.	**K. G. Bakshi,** S. Sinha (Jadavpur University, Kolkata, 700 032, India.)On Zero-Sum Two

	Person Perfect Information Stochastic Games)
7	**Utsav Pandey** (Shiv Nadar University, India), Sanjeet Singh (Indian Institute of Management Lucknow) Combating the outbreak of the COVID pandemic: A study using a two- stage leader-follower DEA model
8	**Kirti Sharma1 ,** V. P. Singh1*, Ali Ebrahimnejad2 and Debjani Chakraborty3 (1* Visvesvaraya National Institute of Technology Nagpur, Nagpur, 440010, Maharashtra, India.2 Islamic Azad University, Qaemshahr Branch, Qaemshahr, Iran.3 Indian Institute of Technology Kharagpur, India.) A hybrid clustering and greedy routing approach to solve a two-level location allocation and a static dial-a-ride problem
9	**Parul Tomar,** Amit Kumar1 Thapar Institute of Engineering & Technology, Patiala-147004, Punjab, India (Mehar method for the solution of fully trapezoidal fuzzy linear programming models)
10	**Prabhjot Kaur1**, Vikas Sharma2, Amarinder Singh3 (1 UIET, Panjab University, Chandigarh,India. 2 School of Mathematics, Thapar University, Patiala, India. 3 Department of Mechatronics Engineering, Chitkara University, Rajpura, Punjab, India) Bottleneck transportation problem over an efficient set of linear objectives
11	**Kirti,** Tina Verma, Amit Kumar1 (Thapar Institute of Engineering & Technology, Patiala, Punjab, India) Modified matrix game-based approach for MADM with probabilistic triangular intuitionistic hesitant fuzzy information

February 2, 2023, Time: 15.45 -18:30 Venue: Seminar Room 1

Technical Session-II B

Chairman : P C Jha, University of Delhi

1.	**G Ravindran** (Indian Statistical Institute, Chennai Centre) Completely mixed games and skew symmetric matrices
2.	**Prerna *,** Vikas Sharma (Thapar Institute of Engineering and Technology, Patiala, India.) Multi- Objective Integer Quadratic Fractional Programming Problem
3.	**Yash Arora1**, Schindiya Laxmi1, S. K. Gupta∗1 (Indian Institute of Technology Roorkee, Roorkee, 247 667, India) Huberized twin support vector machine for binary classification problems
4.	**Punit Kumar Yadav,** K. Palpandi (Malaviya National Instiute of Technology, Jaipur, 302017, India) The weighted vertical linear complementarity problem (wVLCP) on a Euclidean Jordan algebra
5.	D. R. Sahu1 , Feeroz Babu2 and **Shikher Sharma1** (1Department of Mathematics, Banaras Hindu University, Varanasi, 221005, India 2 Department of Applied Mathematics, Aligarh Muslim University, Aligarh, 202002, India)A new self-adaptive iterative method for

	variational inclusion problems on Hadamard manifolds with applications
6.	**Sonali Sharma,** K. Palpandi (Malaviya National Institute of Technology Jaipur, India) A criterion for Q-tensors
7	Rakhee Kulshrestha , **Ajay Singh1**, and Shruti Goel2 (1Birla Institute of Technology and Science, Pilani-333031, India 2Jaypee Institute of Information Technology, Noida, UP-201309, India) Economic Analysis of Discrete-Time Geo/Geo/1 G-Queue with Multi-Optional Services and Bernoulli Feedback
8	**A. Duttaa,**1 and A. K. Das b,2 (a Jadavpur University, Kolkata, 700 032, India b Indian Statistical Institute, Kolkata, 700 108, India) On Some Approaches to Find A Nash Equilibrium of an Oligopolistic Market by means of Nonlinear Complementarity Problem
9	**Jay Chandra Yadav1** Mohammad Rizwanullah2 (Manipal University Jaipur) Optimization of Fuzzy Transportation Problem using New Ranking approach with Fuzzy Numbers
10	**Sibasish Dhibar 1** and Madhu Jain2 (Indian Institute of Technology Roorkee, Roorkee-247667, India.) Metaheuristic Optimization and Joining Strategies for Broken-Down of Retrial Queue

February 3, Time: 10:00 -11:30 Venue: Auditorium

Invited **Session VI**

Chairman: K. Manjunatha Prasad (Manipal Academy of Higher Education, Manipal)

1.	**T. E. S. Raghavan** (University of Illinois at Chicago), Algorithms for structured classes of TU Cooperative games
2	**Agnieszka Wiszniewska-Matyszkiel** (University of Warsaw, Poland) A mathematical model of "the tragedy of the commons" with relation to counteracting pandemic
3.	**Nagarajan Krishnamurthy**(Indian Institute of Management, Indore) Green versus Non-green products: What and how much should manufacturers and retailers choose?

Tea Break: 11:30 -11:45

February 3, 2023 Time: 11.45 -13.15 Venue: Auditorium

Invited **Session VII**
Chairman: S K Neogy (Indian Statistical Institute Delhi Centre)

1.	**Pankaj Gupta** (University of Delhi, India) Vehicle routing under social considerations
2.	**Gajendra Pratap Singh** (Jawaharlal Nehru University, New Delhi) An overview of Boolean and Binary Petri Nets
3	**S.C. Malik** (M.D. University, Rohtak) Reliability Optimization of Non-Repairable Systems of (m, n) Order

Lunch Break: 13:15 -14:00

February 3, 2023, Time: 14:00 -15:30 Venue: Auditorium
Chairman: C S Lalitha (University of Delhi)

Technical Session-III A

1.	FAIZAN AHMAD KHAN 1, **MOHD IQBAL2**, TIRTH RAM2 AND HAMID I. A. MOHAMMED1;3 (University of Tabuk, Tabuk 71491, Saudi Arabia1 University of Jammu, Jammu-180006, India2 University of Bahri, Khartoum 11111, Sudan3) MIXED VARIATIONAL-LIKE INCLUSION INVOLVING YOSIDA APPROXIMATION OPERATOR IN BANACH SPACES
2	**Vrinda Dhingra** a, Amita Sharma b, Shiv K. Gupta a,∗(A Indian Institute of Technology Roorkee-247667, India b Netaji Subhas University of Technology, Delhi-110078, India) Extended Mean expectile-based VaR portfolio model for short selling scenarios by incorporating l1-norm and turnover constraints
3	**Rohit Kumar** Bhardwaj1 and Tirth Ram1 (1University of Jammu, Jammu-180006, India) On approximate vector variational inequalities and vector optimization problem using convexificator
4	**Anveksha Moar** a and C. S. Lalitha b (a b University of Delhi, Delhi-110007;) A Derivative free Descent Method for Solving Set Optimization using Oriented Distance Function
5	**Anna John** (Madurai Kamaraj University, Tamil Nadu) The event-triggered consensus problem of non-linear multiagent systems
6	**Parul Chauhan1**,∗Anjana Gupta1 (1 Delhi Technological University, Bawana Road, Rohini, Delhi, India) 2-person nonzero sum unbalanced linguistic games

February 3, 2023, Time: 14.00 -15:30 Venue: Conference hall

Technical Session-III B
Chairman : K. Manjunatha Prasad (Manipal Academy of Higher Education, Manipal)

1.	**PRADEEP KUMAR SHARMA*** AND C.S. LALITHA (University of Delhi, South Campus, New Delhi, India) CONNECTEDNESS OF THE SOLUTION SETS IN GENERALIZED SEMI-INFINITE SET OPTIMIZATION
2.	**Krishan Kumar** a, Debdas Ghosh a (aDepartment of Mathematical Sciences, Indian Institute of Technology (BHU) Generalized Hukuhara ε-subdifferentiability for interval-valued functions and its applications in nonsmooth optimization
3.	**Anshika** (Joint work with Dr. Debdas Ghosh)(Department of Mathematical Sciences, Indian Institute of Technology, BHU) Analysis of Extended Karush Kuhn Tucker type conditions in Interval Optimization Problems with the help of generalized Hukuhara

	subdifferentiability and the Nonconvex Nonsmooth Composite Model in Interval Optimization
4.	**Nand Kishor (**Joint work with Dr. Debdas Ghosh)(Department of Mathematical Sciences, IIT BHU, Varanasi)Solving Uncertain Multiobjective Optimization Problems using the Cone Method with Minmax Robustness
5.	Priya Sharma* (*Department of Operational Research, University of Delhi) A new multi-attribute group decision-making approach under triangular Pythagorean fuzzy environment
6.	**Rekha*,** Santosh Singh*, and S. K. Neogy**(* Shiv Nadar University, Delhi-NCR, India ** Indian Statistical Institute, New Delhi) Designing and conditioning basis set as memory function for image reconstruction

Tea Break: 15:30 -15:45

February 3, 2023, Time: 15.45 -18:30 Venue: Auditorium

Technical Session-III C

Chairman : T. E. S. Raghavan (University of Illinois at Chicago)

1.	**Faizan Ahemad*** (Department of Operational Research, University of Delhi, Delhi.)Multi-attribute group decision making using projection measure in interval-valued q-rung orthopair fuzzy environment
2.	**Guman Singh1** and Dr. Mohammad Rizwanullah2 (1,2 Manipal University Jaipur, Jaipur) Optimization of Multi -Echelon Reverse Supply Chain Network Using Genetic Algorithm
3.	**Gautam Beniwal** and Dr. Mohammad Rizwanullah (Manipal University Jaipur, India) Optimization of Multi-Objective Problem with Fuzzy Random Variable Using Revised Goal Programming Approach
4.	**Vivek Dhingra**† and N. Kailey† (Thapar Institute of Engineering & Technology, Patiala,, Punjab, India).Higher-order duality results for interval-valued problems with application
5.	**Vijaypal Poonia***, Rakhee Kulshrestha*, Kuldip Singh Sangwan*, Jainil Dharmil Shah* (*BITS Pilani, Pilani Campus, Pilani, Rajasthan, India) Development and Optimization of a Multi-Objective Closed Loop Supply Chain Mathematical Model by Integrating Economic, Environmental and Social Factors: A Case Study of Paint Packaging
6.	**Monika Budania1**(a) Nitin Kumar Mishra1(b) (1Department of Mathematics, Lovely Professional University, Phagwara- 144411, Punjab, India)Study of an inventory model for defective and deteriorating items having two production rates and stochastic demand in a finite planning horizon with permissible delay in payments
7	**Urvashi Godara1**, Shikha Bansal2(1 SRM Institute of Science andTechnology, Delhi-NCR Campus, Ghaziabad, 201204, India 2 SRM Institute of Science and Technology, Delhi-NCR Campus, Ghaziabad, 201204, India) Prediction of Reliability factors for Ceramic Tile Manufacturing System
8	**Arpana Sharma*,** Kanupriya Goswami*, Richa Gupta** (*Keshav Mahavidyalaya, University of Delhi,**Indian Institute of Information Technology,Delhi)Effect of Optimizers in Solving Differential Equations Using Deep Learning

February 3, 2023, Time: 15.45 -18:30 Venue: Conference Hall

Technical Session-IIID

Chairman : Jyoti Dhingra Darbaribi (Lady Shri Ram College, University of Delhi Delhi, India)

1.	Narinder Pushkarna1, Ranjita Pandey2, **Mustafa**3, Firoz Ahmed4 1,2,3 (University of Delhi- 110007 4. Department Management Studies, IIT Roorkee) Integrated Modelling and Analysing the Reliability of Industrial Process Fans
2.	**Ashish Yadav1**, Ritu Arora2(1University of Delhi, India 2Keshav Mahavidyalaya, University of Delhi, India) Uncertainty in Multi-Objective Transportation Problems
3.	B.B. Upadhyay, **Sushil K. Tiwari (Indian Institute of Technology Patna, Bihar)** Optimality and Duality for Geodesic Pseudolinear Programming Problem in Terms of Bifunction on Hadamard Manifolds
4.	**Alka Arya*(**Indian Institute of Management Kashipur, Uttarakhand, 244713, India) Productivity change in two-stage production system for multi-periods with negative data
5.	**Nishtha***1, Jolly Puri1 and Gautam Setia2 (1 2Thapar Institute of Engineering & Technology, Patiala-147001, Punjab, India) Predicting and evaluating efficiency of Indian banks in optimistic and pessimistic environments using DEA-SVR approach
6.	1Abhishek Tandon,2 Anu G. Aggarwal, 3* **Sanchita Aggarwal** (1,2,3Department of Operational Research, University of Delhi, Delhi, India) Understanding the determinants of reviewer credibility: an interpretive structural modeling and artificial neural network approach
7	**Thirumulanathan** D (IIT Kanpur) Deterministic Optimal Mechanisms in Two-item Setting for Constant Power Rate Distributions
8	**Shivani Saini1** and Navdeep Kailey1 (1Thapar Institute of Engineering and Technology, Patiala, 147004, Punjab, India) Relation between a Bilevel Multiobjective Programming Problem and Wolfe Dual

February 3, 2023, Time: 15.45 -18:30 Venue: Seminar Room 1

Technical Session-IIIE

Chairman : Nagarajan Krishnamurthy(Indian Institute of Management, Indore)

1.	Nan Chen1 Jianfeng Cai1 Devika Kannan2 Kannan Govindan2, **Akansha Jain** 3 (1School of Management, Northwestern Polytechnical University, Xi'an 710129, P.R. China) .Optimal channel selection considering price competition and information sharing under demand uncertainty
2.	**Shiwani Sharma** a, Jyoti Dhingra Darbarib, P.C. Jhaa (aDepartment of Operational Research, University of Delhi Delhi, India bDepartment of Mathematics, Lady Shri Ram College, University of Delhi Delhi, India) AN INTEGRATED MATHEMATICAL MODEL FOR 3PRLP SELECTION UNDER SUSTAINABILITY AND RISK CRITERIA

3.	**Dixita Barua** 1, Akansha Jain1, Devika Kannan2, P.C. Jha1 (1 Department of Operational Research, Faculty of Mathematical Sciences, University of Delhi, Delhi2 Department of Technology and Innovation University of Southern Denmark DK-5230 Odense M) A Multi Objective Optimization Model for Facility Selection for Building an Agile and Responsive Circular Supply Chain
4.	Pankaj1, **Rashi Sharma** 2, Rubina Mittal3, P.C. Jha1(1Department of Operational Research, University of Delhi, New Delhi, India 2Lal Bahadur Shastri Institute of Management, New Delhi, India3Keshav Mahavidyalaya, University of Delhi, New Delhi, India) Multi-Objective Approach for Smart Sustainable Supplier Selection and Order Allocation Model within Context of Circular Economy Implementation in Supply Chain Network
5.	B.B. Upadhyay, **Rupesh K. Pandey**, Arnav Ghosh, Savin Treanţă, Indian Institute of Technology Patna, Bihar) Necessary and sufficient optimality conditions for interval-valued optimization problems
6.	**A. K. Das**(Indian Statistical Institute, Kolkata) , Application of optimization problems in game theory
7	**D. K. Mohali** (Sambalpur University) Comparing options and identifying interrelationship of factors for effective paddy procurement for western Orissa
8.	

ABSTRACT OF THE PAPERS

On the Gauss range of a closed convex set

Juan Enrique Martinez-Legaz, Universitat Autnoma de Barcelona, Spain

The aim of this joint work with Cornel Pintea (Babeș-Bolyai University) is twofold. One one hand we study how the Gauss range of a closed convex subset of the Euclidean space changes when acting on the given set with an affine automorphism. On the other hand, we investigate the spherical-convexity of the Gauss range of such a set. Since the Gauss range is not always spherically-convex, we focus our attention on the spherical-convexity of its spherical interior and of its closure as well. Examples of closed convex sets with spherically-convex Gauss ranges are, among others, the epigraphs of suitable lower semicontinuous functions.

Sphere Method-7-6 Using No Matrix Inversions for Linear Programs(LPs)

Katta G. Murty

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Existing software implementations for solving Linear Programming (LP) models are all based on full matrix inversion operations involving every constraint in the model in every step. This linear algebra component in these systems makes it difficult to solve dense models even with moderate size, and it is also the source of accumulating roundoff errors affecting the accuracy of the output. We present a new version of the Sphere method, SM- 7-6, for LP not using any pivot steps.

Approximation schemes for two-level optimization problems

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A two-level optimization problem corresponding to a Stackelberg game in which one of the two players has the leadership in playing the game is considered. In the case in which the response function of the follower is multi-valued, different models are presented as weak and strong Stackelberg solutions, intermediate solutions, and in these cases existence and stability of
solutions and approximate solutions are discussed. These models correspond to a precise behavior of the leader: he can act in an optimistic way (strong) or pessimistic one (weak), or he can gather information and estimate the follower response (intermediate).

In this joint work with G. Carlier a new approximation scheme for a bilevel optimization problem is presented by using Gibbs measures. The existence of solutions and Gamma-convergence results are proved both for optimistic and for pessimistic bilevel problems.

Prospect theoretical extensions of game-theoretical models in wireless communication'

Andreay Garnaev

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Prospect theory, which was introduced by Tversky and Kahneman(``Prospect theory: an analysis of decision under risk,''Econometrica, vol. 47, pp. 263–291, 1979. ), is a method for describing decisions under a subjective factor. In particular, inprospect theory, agents use subjective probabilities (``decision weight"), rather than the objective probabilities, to weigh the values of possible outcomes. Moreover, agents tend to overweight low probability outcomes and under-weight higher probability outcomes.

Besides economics, subjective factors might impact decisions made by decision makers in other fields of human activity. Of course, in game-theoretical models since they involve several agents each of them could be subjective. In this presentation, we show how to develop theoretical extensions of game-theoretical models in wireless communication involving two agents (a user and an adversary) to take into account such subjective factors . In all considered models, prospect theory extensions of equilibrium are designed in closed form, and their uniqueness are proven. Dependence of prospect theoretical extensions of the equilibrium on network and subjective probability parameters are illustrated.

Sequential Jury Voting: A Median Voter Theorem and Beyond

Bo Chen

University of Warwick, UK.

We consider an odd-sized “jury”, which votes sequentially between two equiprobable states of Nature (say A and B, or Innocent and Guilty), with the majority opinion determining the verdict. Jurors have private information in the form of a signal in [−1, +1], with higher signals indicating A more likely. Each juror has an ability in [0, 1], which is proportional to the probability of A given a positive signal, an analogue of Condorcet’s p for binary signals. We assume that jurors vote honestly for the alternative they view more likely, given their signal and prior voting, because they are experts who want to enhance their reputation (after their vote and actual state of Nature is revealed). For a fixed set of jury abilities, the

reliability of the verdict depends on the voting order. For a jury of size three, the optimal ordering is always as follows: middle ability first, then highest ability, then lowest. For sufficiently heterogeneous juries, sequential voting is more reliable than simultaneous voting and is in fact optimal (allowing for non-honest voting). When average ability is fixed, verdict reliability is increasing in heterogeneity. For medium-sized juries, we find through simulation that the median ability juror should still vote first and the remaining ones should have increasing and then decreasing abilities.

A mathematical model of "the tragedy of the commons" with relation to counteracting pandemic

Agnieszka Wiszniewska-Matyszkiel

Institute of Applied Mathematics and Mechanics, University of Warsaw, Poland

Rajani Singh

Department of Digitalization, Copenhagen Business School, Denmark

In this paper, we model the problem of "the tragedy of the commons" that appears when, because of an unpredicted emergency need, a scarce resource becomes a strategic input in a production of the countermeasure to the current threat to the society's safety. The model uses the terminology connected to the squalene market in the context of COVID-19 vaccines with adjuvants based on squalene obtained from endangered deep-sea shark species and it has a compound dynamic game form taking into account various aspects of this market and the privileged position of relatively small number of vaccine producers.

From the economic point of view, the game describes a market consisting of pharmaceutical, cosmetic and shing sector, in presence of a regulatory institution. From the mathematical point of view, we face coupled and hierarchical optimization problems of all the agents, who are elements of two continua and a discrete finite set. We consider Nash and Stackelberg equilibria in which COVID-19 vaccine producers do not take into account their influence on the population of sharks. Using topological and convex analysis tools, we prove the existence and uniqueness of equilibrium together with deriving the formula to find it. We discuss the consequences of relaxing the assumption of vaccine producers myopia concerning sharks.

"The tragedy of the commons" in both cases results in endangering of the vaccination programme: either because of depletion of the shark population or its reduction to a level at which the cost of squalene production exceeds the maximal price that can be paid for it. Various remedies that can be used by the regulating agency are suggested.

Despite using terminology related to a specific problem of high current importance, this may be treated as a starting point to a general theory emphasizing the need to indicate other potential scarce renewable resources for which similar phenomena can appear in the future in order to counteract such risks a priori.

Algorithms for structured classes of TU Cooperative games.

T. E. S. Raghavan

Department of Mathematics, Statistics, and Computer Science,

University of Illinois at Chicago, Chicago, IL 60607-7045

Among the cooperative TU games, the special classes of Standard Tree Enterprise, Assignment games, Connected games and Cyclic permutation games are solvable for locating the nucleolus in polynomial time. The talk will introduce each class and show how the algorithm works for those cases.

Semimonotone matrices and completely mixed games

T. Parthasarathy

Chennai Mathematical Institute, Chennai, India

Study of infinite-server systems driven by Hawkes processes

S Dharmaraja

Department of Mathematics

Indian Institute of Technology Delhi

This talk is devoted to the study of the number of customers in infinite-server systems driven by Hawkes processes. In these systems, the self-exciting arrival process is assumed to be represented by a Hawkes process and the self-exciting service process by a state-dependent Hawkes process (sdHawkes process). For the Hawkes/sdHawkes/∞ system, under suitable conditions, the Markov property of the system is derived. The joint time-dependent distribution of the number of customers in the system, the arrival intensity and the server intensity is characterized by a system of differential equations. Then, the time-dependent results are also deduced for the M/sdHawkes/∞ and M/M/∞ systems.

On nonsmooth V-invexity and vector variational-like inequalities in terms of quasidifferentials

S.K. Mishra

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This talk presents some results which exhibit an application of quasidifferentials in nonsmooth vector optimization problems and vector variational-like inequalities. We give the notion of quasidifferentiable V-invex vector-valued functions and characterize it using V-invariant montonicity in terms of quasidifferentials. We formulate vector variational-like inequalities of Stampacchia and Minty type in terms of quasidifferentials and use these variational-like inequalities as a tool to solve the vector optimization problem involving nonsmooth V-invex functions. We also consider the corresponding weak

versions of the vector variational-like inequalities and establish various results for the weak efficient solutions.

Second-order Optimality Conditions for Geoffrion Proper Efficient Solutions in Nonsmooth Vector Optimization

Rimpi[a], Aanchal[a] and C. S. Lalitha[b]
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[b]Department of Mathematics, University of Delhi South Campus, Benito Juarez Road, New Delhi-110 021, India

The main aim of the talk is to present strong second-order necessary optimality conditions for the existence of a local Geoffrion proper efficient solution of vector optimization problems with equality, inequality and abstract set constraints. Both primal and dual forms of second-order necessary optimality conditions are derived for problems with regular equality constraints in the absence of any regularity or constraint qualification assumptions. Assuming a calmness condition, a dual form of second-order sufficient optimality conditions is derived for problems with regular equality constraints.

Vehicle routing under social considerations

Pankaj Gupta

Department of Operational Research, University of Delhi, Delhi, India

Using qualitative and quantitative research methods and combining text analytics and combinatorial optimization to model social problems is a relatively new concept in the vehicle routing literature. Therefore, an integrated routing model is developed using various sources and types of data, viz., structured data for routing and unstructured data for topic modelling, to obtain solutions for routing under social considerations.

Ranking of DMUs in a Peer Group Competitive Environment

Sanjeet Singh

Decision Sciences Area, Indian Institute of Management Lucknow, India.

Rankings play an important role in improving the performance of Decision Making units (DMUs). Rankings are not only important for firms to understand the current state of affairs but also for future course correction to stay in the competition. Cross efficiency in Data Envelopment Analysis (DEA) is among a very few mathematical techniques which have been widely used for the peer group ranking of DMUs. This lecture presents a brief overview of the various ranking approaches in DEA by taking a journey from self-evaluation to peer evaluation of DMUs in a competitive environment.

Stochastic Nash games under chance constraints

Vikas Vikram Singh

Indian Institute of Technology Delhi, India

The strategic games with stochastic payoffs and constraints have been extensively studied in the literature. The case of risk neutral decision makers has been studied by considering the expectation of random payoffs and constraints. We use chance constraint programming to model the risk averse stochastic Nash games. We show the existence of Nash equilibrium for the case of elliptically symmetric distributions. We also consider the case where underlying probability distribution is only known to belong to a distributional uncertainty set. These cases are modelled by considering the worst case situation using distributionally robust approach. We show the existence of Nash equilibrium for various distributional uncertainty sets and discuss some computational approaches to compute the Nash equilibrium for these games.

Sequential learning in a stochastic multi armed bandit framework

Sandeep Juneja,

Tata Institute of Fundamental Research, Mumbai, India

The classic stochastic multi armed bandit framework involves finitely many unknown probability distributions that can be sequentially sampled to generate independent rewards. In this talk we consider two foundational problems: First one corresponds to sampling to minimize the expected regret, or equivalently, to maximize the expected total reward. The second one corresponds to the best arm identification, i.e., identifying the arm with the largest mean, or any other performance measure, using as few samples as possible while providing explicit probabilistically correct selection guarantees. These problems form the bedrock of algorithms used in web design and advertising, recommendation systems, clinical trials and many other exciting applications. In this talk we review some of the popular algorithms used for these problems emphasizing the intuition underlying the elegant ideas. Technically speaking, these problems have been well studied under the restrictive assumption that arm distributions belong to a single parameter exponential family, that includes distributions such as Bernoulli and Gaussian with known variance. Under these settings, lower bounds on samples needed are developed using ideas from hypothesis testing, and algorithms are proposed that match the lower bound. We propose optimal algorithms that match the lower bounds even to a constant for general probability distributions under minimal restrictions.

Generalized Inverses in Network Optimization Problems

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Green versus Non-green products: What and how much should manufacturers and retailers choose?

Nagarajan Krishnamurthy,
Indian Institute of Management, Indore

This work considers the scenario where manufacturers have to choose between green and non-green products, and models the same as a noncooperative game. Under some assumptions, we show that the choice of manufacturing green products is a dominant strategy for each manufacturer and, hence, each manufacturer choosing to manufacture green products is the unique Nash equilibrium of the game. These results extend to the game between retailers too, where each retailer may choose to sell green products versus non-green products. The work, furthermore, models and studies the interaction between a manufacturer and a retailer in the context of green versus non-green products. This is joint work with Manish Kumar, IIM Indore.

On an Analogue of a Property of Singular M-matrices, for the Lyapunov and the Stein Operators

K.C. Sivakumar∗

Indian Institute of Technology Madras, India.

Let A be a singular irreducible M-matrix. Then the only nonnegative vector that belongs to the range space of A is the zero vector. An analogue of this result is proved for the Lyapunov and the Stein operators.

** Joint work with A.M. Encinas (Barcelonatech, Spain) and Samir Mondal (IIT Madras).*

On optimality in contest theory models of long-run advertising and short-run competition

Reinoud Joosten, Rogier Harmelink, Tom Sparrius∗

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This paper is a continuation and extension of earlier efforts by one of us in applying advanced forms of (stochastic) game theory1 to settings from industrial organization (cf., Joosten [2009,2016]). Both contributions feature a combination of competitive advertising in the (infinitely repeated) long run and strategic behavior in the short run in a specific additional strategic variable. Joosten [2009] merely assumed each short-run outcome to result from a Cournot equilibrium in the stage game generated by the materialization of advertisement decisions until then. Consequently, Joosten [2009] employed stochastic game theory to obtain optimality, i.e., establish Nash equilibria, regarding the advertisement strategies in

the infinitely repeated game. Joosten [2016] tackled the part of its predecessor merely covered by assumptions by modeling the short run phase explicitly, assuming a rich structure connecting past advertising decisions and the momentary strategic environment, mainly captured in the momentary (inverse) demand functions.

Our first extension which in our view should be considered as a minor one, deals with the short term competition phase. We extend and unify to some degree, the approaches mentioned by examining standard outcomes of competition distinguished in industrial organization to occur, i.e., Cournotequilibrium, Bertrand equilibrium, leader-follower competition in quantities (Stackelberg-Cournot) and in prices (Stackelberg-Bertrand), collusion in quantities and in prices.

Our other extension involves one of the building blocks of Joosten [2016] which adds another level of explanation and motivation to model the consequences of materialized past advertising decisions on current demand functions. We assume that a certain demand enhancing effect, common to both firms, occurs and that the division of the benefits among them depends on their past advertisement efforts relative to the total efforts, in line with standard modes of modeling in contest theory (cf., e.g., Vojnovi´c [2015]). For this novel approach in this framework, we choose the simplest variant of the possibilities available in the literature regarding Contest Success Functions (cf., e.g., Vojnovi´c [2015]), but conceptually our approach does not hinge on the specific choice of such a function, provided it is continuous.

Having made clear what the extensions to the general program are first, we now state our overall modeling aims and intentions. We model and study strategic interaction over time in a duopolistic market in which advertising causes different types of externalities in the time-dimension. We engineer a game with joint frequency dependent stage payoffs which allows us to build in rather complex relationships over time, and analyze it with modifications of techniques traditionally used for infinitely repeated games. We refer to Joosten et al. [2003] for the earliest contribution leading up to an extended class of stochastic games, called ETP-ESP games, and to Joosten & Samuel [2020] for an overview of the latter class.

A New Beginning in Computational Complexity of Combinatorial Optimisation problems •Why study Pedigree Polytopes?

Tiru Arthanari,

The University of Auckland, New Zealand

In this talk, we explain how the computational complexity of the symmetric travelling salesman problem is proved to be polynomial in the size of the instance. This is not an expected result by most theoretical Computer Scientists, Operations Researchers and Mathematicians.

We will follow the presentation accessible to operations researchers with a background in Combinatorial Optimisation and polyhedral combinatorics. The main departure from the traditional attack on solving an *NP-complete* problem is that we study the linear optimisation over the pedigree polytope. *Pedigree* is a combinatorial object introduced and studied by the author. There is a 1-1 correspondence between pedigrees and Hamiltonian cycles.

Also, we introduce constructions not studied earlier for other combinatorial optimisation problems. The details of the results and the proofs are given in a forthcoming book by Springer Nature, entitled:
Pedigree Polytopes- New Insights on Computational Complexity

Reliability Optimization of Non-Repairable Systems of (m, n) Order

S.C. Malik

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The structural designs of the components in non-repairable systems have played a significant role in improving their reliability. It has been proved that parallel structure of the component is better than that of series so far as reliability is concerned. In the fast growing age of technology we are now in a comfort position to make use of several structures such as series, parallel, series-parallel, parallel-series and k-out-of-n to develop the systems with considerable reliability. On the other hand, the purpose of the system designers is not only to make the system with high reliability but also to make an optimal balance between reliability and manufacturing cost of the systems. In such situations it becomes necessary to determine the optimal number of components and optimal number of sub-systems required for the development of the systems with minimum cost to achieve the maximum reliability. The reliability of non-repairable systems is heavily dependent on the structure of the components and therefore, the focus of this talk will be on the methodology to determine the number of components and sub-systems required for the optimization of reliability through various structures. The reliability measures of some well known structures such as series, parallel, parallel-series of (m, n) order and series-parallel of (m, n) order for the non-repairable systems have been evaluated by considering negative exponential distribution for the failure rate of the components. The behavior of these measures with respect to number of components, operating time and failure rate of the components has been observed for some particular cases of these systems.

An overview of Boolean and Binary Petri Nets

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Petri Nets is a formalized mathematical tool that we use for the analysis of discrete-event-based systems. A wide range of Petri net theories have been proposed for improving system modeling based on the requirements in various fields. The Boolean Petri Nets [1,2] are a special class of Petri Nets that are 1-safe with some restrictions on the net elements and generate every binary vector as a marking vector. In this paper we show some good results in the theory of Boolean Petri Nets and extend the idea to Binary Petri Nets [3,4]. Based on an analysis of Binary Petri Nets, it is evident that they generate binary reachability trees. Mathematical and computer science terms BOOLEAN and BINARY have similar meanings and have wide applicability in diverse domains

Nominations for Best Paper Award

ESTIMATION OF STRUCTURED DISTANCES TO SINGULARITY FOR MATRIX PENCILS WITH SYMMETRY STRUCTURES: A LINEAR ALGEBRA--BASED APPROACH

(SIAM J. MATRIX ANAL. APPL. © 2022 Vol. 43, No. 2, pp. 740—763)

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Abstract. We study the structured distance to singularity for a given regular matrix pencil $A + sE$, where $(A, E) \in \mathbb{S} \subseteq (\mathbb{C}^{n,n})^2$. This includes Hermitian, skew-Hermitian, $*$-even, $*$-odd, $*$-palindromic, T-palindromic, and dissipative Hamiltonian pencils. We present a purely linear algebra-based approach to derive explicit computable formulas for the distance to the nearest structured pencil $(A-\Delta_A)+s(E-\Delta_E)$ such that $A-\Delta_A$ and $E-\Delta_E$ have a common null vector. We then obtain a family of computable lower bounds for the unstructured and structured distances to singularity. Numerical experiments suggest that in many cases, there is a significant difference between structured and unstructured distances. This approach extends to structured matrix polynomials with higher degrees.

A new subclass of Q0-matrix in linear complementarity theory

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In this article, we introduce a new matrix class $\bar{L}(d)$ (a subclass of Q_0-matrices which are obtained as a limit of a sequence of $L(d)$-matrices) such that for any A in this class, a solution to LCP(q, A) exists if LCP(q, A) is feasible, and Lemke's algorithm will find a solution or demonstrate infeasibility. We present a counterexample to show that an $\bar{L}(d)$-matrix need not be an $L(d)$-matrix. We also show that if $A \in \bar{L}(d)$, there is an even number of solutions for any nondegenerate vector q. An application of this new matrix class that arises from general quadratic programs and polymatrix games belongs to this class. Finally, we present an example related to the existence of equilibrium in polymatrix games.

OPTIMALITY CONDITIONS AND DUALITY FOR MULTIOBJECTIVE

SEMI-INFINITE PROGRAMMING PROBLEMS ON HADAMARD MANIFOLDS

USING GENERALIZED GEODESIC CONVEXITY

(RAIRO-Oper. Res. 56 (2022) 2037–2065)

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Abstract. This paper deals with multiobjective semi-infinite programming problems on Hadamard manifolds. We establish the sufficient optimality criteria of the considered problem under generalized geodesic convexity assumptions. Moreover, we formulate the Mond-Weir and Wolfe type dual problems and derive the weak, strong and strict converse duality theorems relating the primal and dual problems under generalized geodesic convexity assumptions. Suitable examples have also been given to illustrate the significance of these results. The results presented in this paper extend and generalize the corresponding results in the literature.

On almost semimonotone matrices and the linear complementarity problem☆

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In this paper, we revisit the class of almost (strictly) semimonotone matrices and partially address the conjecture made by Wendler [Spec. Matrices 7 (2019) 291–303]. We disprove the second part of the conjecture by providing a counter example. The main result of this paper shows that Wendler's conjecture is true under the symmetry assumption. We explore some interesting matrix theoretic properties of almost (strictly) semimonotone matrices and also present results pertaining to the existence and multiplicity of solutions to the linear complementarity problem associated with an almost semimonotone matrix.

On Semimonotone Matrices, R0-Matrices and Q-Matrices

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Abstract

In 1979, Pang proved that within the class of semimonotone matrices, R_0-matrices are Q-matrices and conjectured that the converse is also true. Jeter and Pye gave a counterexample when $n = 5$ for the converse; namely, they gave a semimonotone matrix that is in Q but not in R_0. In this paper, we prove this conjecture for semimonotone matrices of order $n \leq 3$ and provide a counterexample when $n > 3$, showing the sharpness of the result. We also provide an application of this result.

Characterization of the dissipative mappings and their application to perturbations of dissipative-Hamiltonian systems

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Abstract

In this article, we find necessary and sufficient conditions to identify pairs of matrices X and Y for which there exists $\Delta \in \mathbb{C}^{n,n}$ such that $\Delta + \Delta^*$ is positive semidefinite and $\Delta X = Y$. Such a Δ is called a dissipative mapping taking X to Y. We also provide two different characterizations for the set of all dissipative mappings, and use them to characterize the unique dissipative mapping with minimal Frobenius norm. The minimal-norm dissipative mapping is then used to determine the distance to asymptotic instability for dissipative-Hamiltonian systems under general structure-preserving perturbations. We illustrate our results over some numerical examples and compare them with those of Mehl, Mehrmann, and Sharma (Stability radii for linear Hamiltonian systems with dissipation under structure-preserving perturbations, *SIAM J Matrix Anal Appl*, 37(4):1625–54, 2016).

KEYWORDS

dissipative-Hamiltonian systems, positive semidefinite matrix, stability radius, structured mapping problems, structured stability radius

Constraint qualifications in terms of convexificators for nonsmooth programming problems with mixed constraints

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OPTIMIZATION

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ABSTRACT

The main aim of the paper is to introduce certain constraint qualifications for a nonsmooth programming problem in terms of semi-regular convexificators and investigate their relations with other existing notions of constraint qualifications. The programming problem under consideration has mixed constraints, that is, it involves both inequality and equality constraints. All these notions are in terms of upper semi-regular convexificators of inequality constraints and pseudo-differentials of equality constraints. Based on a sufficient condition for error bound property, the implication relation between quasinormality and error bound property in terms of convexificators is investigated in this paper. Three conditions are introduced, namely constant positive linear dependence condition (CPLD), constant rank constraint qualification (CRCQ) and Mangasarian–Fromovitz constraint qualification (MFCQ) in terms of convexificators. These conditions are in fact shown to be constraint qualifications as Karush–Kuhn–Tucker optimality conditions hold when CPLD holds and both MFCQ and CRCQ imply CPLD. Further, it is observed that CPLD and quasinormality conditions are independent for nonsmooth problems in terms of convexificators.

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Completely mixed games and skew symmetric matrices*

G Ravindran

Indian Statistical Institute, Chennai Centre

(The talk will be based on my recent work with Mr Sunil and T P.arthasarathy)

On Nonsmooth Interval-valued Multiobjective Programming Problems and Generalized Stampacchia Vector Variational Inequalities

B. B. Upadhyay

Indian Institute of Technology Patna

In this talk, I will discuss the relationship between nonsmooth interval-valued multiobjective programming problem and generalized Stampacchia vector variational inequality problem along with its weak form for interval-valued functions. We have employed the tools of Mordukhovich subdifferential to define some new classes of generalized approximate LU-convex functions. These functions are then utilized to establish the relations between the solutions of generalized vector variational inequalities and the approximate LU-efficient solutions of the nonsmooth interval-valued multiobjective programming problem. Moreover, we identify the Kuhn-Tucker vector critical points of the considered nonsmooth interval-valued multiobjective programming problem. Under suitable constraint qualification, we establish the equivalence among local approximate LU-efficient points, KuhnTucker vector critical points and the solutions of generalized Stampacchia vector variational inequalities. The results discussed in the talk extend and sharpen several previously known results in theliterature.

Cross efficiency approach for non-homogeneous parallel sub-units: A case of ranking in higher education

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This research is inspired from the growing concern of ranking of higher education sector in India. This paper proposes cross efficiency approach to rank Decision Making Units (DMUs) having non-homogeneous parallel sub-unit system. In non-homogeneous parallel sub-units system, a DMU consists of several non-homogeneous parallel sub-units. Each non-homogeneous sub-unit of a DMU has a counterpart in other DMUs. Proposed approach measures the cross efficiency of a DMU and its sub-units simultaneously. Cross efficiency of a DMU is equal to the convex combination of the cross efficiencies of its sub-units. And weights of sub-units can be assigned a priori by the decision maker. The advantage of this approach is that the efficiency of the DMU is sensitive to the changes in the efficiency of its sub-units. This research is motivated by the growing concern of ranking in higher education sector of India. The proposed application considers states as DMUs, and universities, colleges and stand-alone institutions as three non-homogeneous parallel sub-units of DMUs.

1_4 DEVELOPMING AN MODEL FOR ASSESSMENT OF SUBJECTIVE ANSWAR USING DATA ENVELOPMENT ANALYSIS

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In this paper an attempt has been made to purpose a method using a Multi Criteria Decision Making (MCDM) tool i.e. Data Envelopment Analysis (DEA). So that the proposed model will can be utilised todevelop an automate software for the evaluation of the descriptive script.

2_6 Unbiased scalarization technique for multi-objective fractional feed formulation problem

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This article proposes an efficient technique to solve multi-objective fractional programming problems (MOFPPs). We first convert MOFPP into a multi-objective optimization problem by introducing a generalized Charnes-Cooper transformation. The converted problem is shown to be equivalent to that of the original one. Then a scalarization technique is developed to find efficient solutions for the converted multi-objective optimization problem. We further discussed the analytical properties of the proposed scalarization technique. The technique is illustrated using several test problems and then a feed blend problem is selected for the study. The feed formulation model optimizes the cost, nutritional, nutritional-environmental, and environmental criteria with four conflicting objectives.

3_7 Nonsmooth vector variational inequalities and Nonsmooth Vector optimization problems on Hadamard manifold

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Aligarh Muslim University, Aligarh-202002, India

The concept of bifunction and geodesic convexity for the vector valued functions on the Hadamard manifold is defined in this paper. A non-trivial example is constructed in sup- port of our definition. Furthermore, non-smooth vector variational inequalities problems (NVVIP) and Minty non-smooth

vector variational inequalities problems (MNVVIP) are defined on the Hadamard manifolds. Using the vector valued bifunction h, geodesic h-convexity, geodesic h-pseudoconvexity and geodesic h-quasiconvexity have been introduced and several properties of them have been studied. We exhibit the uniqueness of the solution of NVVIP and discuss a relationship between the solutions of NVVIP and MNVVIP. Afterwords, a nonsmooth vector optimization problem (NVOP) has been considered and relationships among the solutions of NVOP, NVVIP and MNVVIP have been investigated.

4_8 Duality results for interval-valued semi-infinite optimization problems with equilibrium constraints using convexificator

S. K. Mishra and **Mohd Hassan**

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This paper deals with the study of interval-valued semi-infinite optimization problems with equilibrium constraints (ISOPEC) using convexificators. First, we formulate Wolfe type dual problem for (ISOPEC) and establish duality results between the (ISOPEC) and the corresponding Wolfe type dual under the assumption of ∂-convexity. Second, we formulate Mond-Weir type dual problem and propose duality results between the (ISOPEC) and the corresponding Mond-Weir type dual under the assumption of ∂-convexity, ∂-pseudoconvexity, and ∂-quasiconvexity.

5_9. Hermite-Hadamard-Jensen-Mercer type inequalities for strongly convex functions via Ψ-Riemann-Liouville k-fractional integrals

Shashi Kant Mishra, **Soumya Rath,** Jaya Bisht

Institute of Science, Banaras Hindu University

In this paper, we establish Hermite-Hadamard-Jensen-Mercer type inequalities for Ψ-Riemann-Liouville k-Fractional integrals by employing Jensen-Mercer's inequality for strongly convex functions. Further, we investigate the left side and right side of fractional Hermite-Hadamard-Jensen-Mercer type inequalities for differentiable functions whose derivatives are convex. Several known results are recollected as special cases to our results.

6_14 Ostrowski type inequalities via some exponentially s-preinvex functions on time scales with applications

S. K. Mishra and **Vandana Singh**

Institute of Science, Banaras Hindu University

In this paper, we establish Ostrowski type inequalities for exponentially s-preinvex and s-preinvex functions on time scale. We also obtain applications to some special means. Moreover, we discuss several special cases of the results obtained in this paper.

7_20 Moore-Penrose inverse of distance Laplacian matrices of trees are Z matrices

R. Balaji

Let T be a weighted tree on n vertices and $D(T) := [d_{ij}]$ be the distance matrix of T. The distance Laplacian matrix of T is then the matrix

$$L_D(T) := \mathrm{Diag}(\sum_{j=1}^{n} d_{1j}, \ldots, \sum_{j=1}^{n} d_{nj}) - D(T).$$

We show that all off-diagonal entries in the Moore-Penrose inverse of $L_D(T)$ are non-positive.

8_21 On optimization problems using quasidifferentiability

Vivek Laha *

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The aim of this talk is to discuss optimization problems involving quasidifferentiable functions. The talk presents suitable optimality conditions based on some recent works in fractional programming and variational inequaliites in terms of quasidifferentials. The presentation deals with Fritz-John (FJ) and Karush-Kuhn-Tucker (KKT) type necessary optimality conditions at an optimal point in the framework of the quasidifferentiable analysis. Further, several other applications of the results are investigated in different fields of optimization like mathematical programs with equilibrium constraints.

9_24 More On Modulus Based Iterative Method For Solving Implicit Complementarity Problem

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The implicit complementarity problem (ICP), introduced by Bensoussan et al. in 1973. The linear complementarity problem (LCP) is a special case of the ICP and the ICP is used in many fields, such as engineering and economics, scientific computing, stochastic optimal control problems and convex cones. Consider the matrix $A_1 \in R^{n\times n}$ and the vector $q \in R^n$. The linear complementarity problem denoted as ICP(q, A_1, ψ) is to find the solution $z \in R^n$ to the following system:

$$p(z) = A_1 z + q \geq 0, \quad q(z) = z - \psi(z) \geq 0, \quad q(z)^T p(z) = 0, \tag{1}$$

where $\psi(z)$ is an invertible mapping from R^n into R^n such that $q(z)$ is invertible. If $\psi(z) = 0$ in Eq.(1), the ICP(q, A_1, ψ) reduce to the linear complementarity problem (LCP(q, A_1)). Many methods, such as fixed point approaches, projection-type methods, smooth and nonsmooth Newton methods, linearization methods, domain decomposition methods, matrix multisplitting methods and inexact alternating direction methods, have been proposed in recent decades to solve complementarity problems by considering some equivalent problems. In 2016, Hong and Li demonstrated numerically the superiority of the modulus-based matrix splitting (MMS) method over the projection fixed-point method and the Newton method when solving the ICP(q, A_1, ψ). Shilang and Liang presented a family of new modulus-based matrix splitting (NMMS) iteration methods to solve the ICP(q, A_1, ψ) in 2022. The NMMS method was not only different from the inner-outer iteration methods. In addition, the NMMS method was simple and efficient in its implementation. Motivated by Shilang and Liang, we propose a Modified modulus-based iterative method based on new matrix splitting for solving ICP(q, A_1, ψ), which covers the NMMS method and it is more efficient than the NMMS method. First, we construct a new equivalent expression of the ICP(q, A_1, ψ). The details are as follows. Let $A_1 \in R^{n\times n}$, ϕ_1 and ϕ_2 are positive diagonal matrices. Then the ICP(q, A_1, ψ) is equivalent to

$$\begin{aligned}(M_{\phi_1} + \phi_{\phi_1} + \phi_2)z = [(N_{\phi_1} + \phi_{\phi_1})z + [(A_{\phi_1} - \phi_2)z + \phi_1 q + \phi_2\psi(z)] \\ - \phi_1 q + \phi_2\psi(z)].\end{aligned} \tag{2}$$

By using Eq.(2), we obtain

$$z^{(k+1)} = (M_{\phi_1} + \phi_{\phi_1} + \phi_2)^{-1}[(N_{\phi_1} + \phi_{\phi_1})z^{(k)} + |(A_{\phi_1} - \phi_2)z^{(k)} + \phi_1 q + \phi_2\psi(z^{(k)})| - \phi_1 q + \phi_2\psi(z^{(k)})|, \tag{3}$$

which is a new iterative method for solving ICP, this iterative method is referred to as "Modified modulus-based iterative method " for solving ICP(q, A_1, ψ) and shows that the solution of fixed point Eq.(3) is equivalent to the ICP(q, A_1, ψ). We provide the general convergence condition when the system matrix A_1 is a P-matrix and some sufficient conditions for the convergence when the system matrix A_1 is an H_+-matrix or strictly diagonally dominant matrix. To show the effectiveness of the proposed method some numerical examples are discussed.

10_25 Optimization of the coating parameters of electroless Ni-Co-P coating using Artificial Bee Colony Algorithm

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The corrosion resistance property of Copper has been enhanced by depositing Ni-Co-P coating following electroless technique in this present experimental work. The coating was deposited from an acidic bath containing Nickel Sulphate, Cobalt Sulphate, Sodium Hypophosphite, Tri-sodium Citrate Dihydrate and Ammonium Sulphate. The electroless Ni-Co-P coating was deposited at bath temperature ranging between 76.44–93.45°C. A second order predictive model has been developed using Response Surface methodology to predict the corrosion rate of electroless Ni-Co-P coating. The second order Response Surface model is developed considering corrosion rate as response and using rotatable second order Central Composite Design of experiment by varying the concentration of Cobalt Sulphate, Sodium Hypophosphite and bath temperature. The corrosion rate was experimentally determined through Potential Dynamic test using 3.5% NaCl solution. The corrosion current density was measured using the Tafel plot. The surface morphology was analyzed and compared from the Scanning Electron micrographs of the coated surface before and after corrosion test. Artificial Bee Colony (ABC) algorithm has been used to evaluate the optimum values of the concentration of Cobalt ion source, reducing agent and bath temperature to minimize the corrosion test. In ABC algorithm the optimal values of the process

parameters were encoded as a food source. The fitness of the trial solution is determined by the nectar amount of a food source. The electroless Ni-Co-P coating was again deposited at the condition identified from the ABC algorithm for minimization of corrosion rate for confirmation run. The Tafel test establishes that the corrosion rate has been minimized in the confirmation run. The electrolessly deposited Ni-Co-P coated samples at the optimum condition has been tested under Energy Dispersive xray analysis (EDX) for the weight percentage of Nickel, Cobalt and Phosphorous. The surface morphology before and after corrosion test of the samples prepared at optimal condition has been compared using the SEM images.

11_26 A Class of Quasi-Variational Inequalities with Unbounded Constraint Maps: Existence Results and Applications

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The quasi-variational inequalities play a significant role in analysing a wide range of real-world problems. However, these problems are more complicated to solve than variational inequalities as the constraint set is based on the current point. We study a class of quasi-variational inequality problems whose specific structure is beneficial in finding some of its solutions by solving a corresponding variational inequality problem. Based on the classical existence theorem for variational inequalities, our main results ensure the occurrence of solutions for the aforementioned class of quasi-variational inequalities in which the associated constraint maps are (possibly) unbounded. We employ a coercivity condition which plays a crucial role in obtaining these results. Finally, we apply our existence results to ensure the occurrence of equilibrium for the pure exchange economic problems and the convex generalized Nash games.

12_27 Hermite-Hadamard type inclusions for interval-valued coordinated Preinvex functions

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In this paper, we introduce the concept of interval-valued preinvex functions on the coordinates in a rectangle from the plane and prove Hermite-Hadamard type inclusions for interval-valued preinvex functions on coordinates. Further, we establish Hermite-Hadamard type inclusions for the product of two interval-valued coordinated preinvex functions. Our established results generalize and extend some recent

results obtained in the existing literature. Moreover, we provide suitable examples in the support of our theoretical results.

13_29 On interval-valued multiobjective semi-infinite programming .

Akriti Dwivedi* and Vivek Laha

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The talk is devoted to the study of a nondifferentiable interval-valued multiobjective semi-infinite programming problem (IVMOSIP) involving locally Lipschitz functions. We first introduce approximate versions of some constraint qualifications available insemi-infinite programming for the IVMOSIP and derive necessary optimality conditions to identify approximate quasi efficient solutions under these approximate constraint qualifications. We also deduce the conditions under which the KKT type necessary optimality conditions become sufficient under the assumptions of approximate convexity. An approximate dual model of Mond-Weir type is used to generate primal- dual relations and to obtain duality results. The tool of Clarke subdifferential from nonsmooth analysis has been used to attain the required results which are well illustrated by examples.

14_30 On multiobjective optimization and vector variational inequalities using convexificators

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This talk deals with some results which exhibit an application of directional convexificators in multiobjective optimization problems (MOPs) and vector variational inequaities (VVIs) involving lower semicontinuous functions. We formulate vector variational inequalities of Stampacchia and Minty type using directional convexificators which in turn are used to find out necessary and sufficient optimality conditions for efficiency of a feasible point of the MOP. We also formulate weak versions of the vector variational inequalities and establish several results to find out weak efficient solutions. In particular, we extend the results of Gadhi [On variational inequalities using directional convexificators, Optimization (2021), DOI: 10.1080/02331934.2021.1888088] to the multiobjective case, the results of Laha and Mishra [On vector optimization problems and vector variational inequalities using convexificators. Optimization, 66(11), 1837-1850] and Laha et al. [On nonsmooth multiobjective semidefinite programs and vector variational inequalities using convexificator] to the lower semicontinuous case. The results are well illustrated by examples.

15_33 Existence Theorems on Quasi-variational Inequalities over Banach Spaces and its Applications to Time-dependent Pure Exchange Economy

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We will discuss a class of quasi-variational inequality problems defined over infinite dimensional Banach space. Under this discussion, we deduce sufficient conditions for ensuring solutions to such problems under the upper semi-continuity and pseudo-monotonicity assumptions on the map defining the inequalities. This special type of quasi-variational inequalities is motivated by the pure exchange economic problems and Radner equilibrium problems for sequential trading game. The special structure of the quasi-variational inequality enables us to show the occurrence of solutions for such inequalities based on the classical existence theorem for variational inequalities. Further, we study the solvability of these specific quasi-variational inequalities on Banach spaces considering that the constraint map may admit unbounded values. Finally, we demonstrate the occurrence of dynamic competitive equilibrium for a time-dependent pure exchange economy as an application.

16_34 A Derivative-free Descent Method for Solving Set Optimization using Oriented Distance Function

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In this presentation, a descent method is proposed for solving a set optimization problem. We consider the following set optimization problem

$$\begin{array}{lll} (\mathrm{P}) & \text{Minimize} & F(x) \\ & \text{subject to} & x \in X. \end{array}$$

where $F : X \rightrightarrows Y$ is a K-convex set-valued mapping and X, Y are real normed linear spaces. Kuroiwa considered various set order relations for comparing sets and to define solution concepts based on them. In set optimization, scalar-ization is a widely used technique for comparing the sets while using descent algorithms. Various scalarizing functions are used to characterize the set order relations. We consider the solution concept based on one of the set order relation, namely lower set order relation and use the oriented distance function to provide a scalar characterization of the set order relation. In particular, we provide the characterization of polyhedral sets in terms of oriented distance function. We also characterize lower set order relation with respect to polyhedral cones. Using the scalar characterization a descent method is developed where descent direction is computed using derivative free approach and follow the classical backtracking procedure of Armijo's like rule for the line search. Some numerical examples are also presented to illustrate the performance of the method.

17_37 Game Theoretic Model on Sharing Infrastructure Among Battery Swapping Stations

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In this paper, we formulate the swapping problem as a cooperative game and identify situations in which resource sharing is beneficial, and the allocation scheme is at the core. Battery Swapping Station (BSS) can either operate its own station or request a swap in a distant market to provide reliable service to mitigate the loss in consumer goodwill. The game-theoretical model explains battery sharing among independent BSS to fulfill distant consumer demand while minimizing infrastructure investment. The proposed model provides an allocation mechanism that could ensures BSS's future demand while penalizing free riders, which can easily be implemented in practice and designed to optimize resource redistribution in the market. Further, the paper demonstrates that our model embedded with a single attribute function has a non-empty core with a population monotonic allocation scheme.

18_38 New approaches of extending energy optimal topology on interval graph model of wireless sensor networks with sensitivity analysis

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Topology control in wireless sensor networks has been greatly influenced by energy efficient tree topologies, engaged with immobile sensor nodes. The existing optimal topologies lack dynamic applicability of wireless sensor networks due to nodes immobility and less stable with the removal of old nodes or addition of new nodes. In this article, we work to extend the applicability of the most recent energy optimal tree topology, obtained on interval graph model of wireless sensor networks with respect to addition of one or more new nodes to the existing topology. To cope up with nodes immobility with lesser time complexity in reorganizing the existing topology on addition of new nodes, new algorithmic approaches have been proposed to provide the extension to the optimal topology in such a way that no or minimum change is seen in maximum power consumption on the extended topology. Sensitivity analysis on addition of one and multiple new nodes to many energy optimal topologies of distinct interval graphs and evaluation of change in optimal value of maximum power consumption on every extended topology in compare to its optimal topology have been provided in detail with all the possible results.

19_42 On the invariance of profiles and convergence of replicator trajectories in quadratic games

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Indian Institute of Technology Madras

We provide a new class of special solutions to the replicator dynamics defined on two population asymmetric games with one-dimensional real strategy sets and quadratic payoff functions. We prove that the set of profiles of Gaussian measures is invariant under the two population asymmetric replicator dynamics for this class of games. This generalizes the invariance results for symmetric games with quadratic payoff functions first given by Oechssler and Riedel (2002) and later extended by Cressman (2005). The results on the existence and uniqueness of solutions for the infinite replicator in the symmetric case were first given by Bomze (1989). Oechssler and Riedel (2001) proved that the boundedness and measurability of the payoff function are sufficient conditions to guarantee the existence and uniqueness of solutions in the symmetric case. The existence and uniqueness of solutions for the asymmetric replicator dynamics for bounded measurable payoff functions were proved by Mendoza-Palacios and Hernández-Lerma (2015). There are no general results on the existence and uniqueness of the replicator dynamics when the payoff functions are unbounded. Our result establishes the existence and uniqueness of solutions when the payoffs are quadratic functions and the initial conditions are Gaussian profiles. We then study the replicator dynamics on the invariant space of Gaussian profiles. For this restricted dynamical system, we prove the weak convergence of trajectories to Dirac measure profiles on certain lines for a subclass of quadratic payoff functions using the-Wasserstein distance. This subclass of quadratic payoff functions is seen to arise naturally from the structure of a two-dimensional linear time-varying dynamical system governing the evolution of means of the Gaussian profiles. We provide an example in this subclass for which all points in the weak attractor are strict Nash equilibria and maximize the mean fitness function. For payoff functions that are not in this subclass, theoretical results are not yet known. In this case, the stability of profiles and convergence of the trajectories are studied using simulations.

20_43 SET-VALUED OPTIMIZATION PERSPECTIVE OF BILEVEL PROGRAMMING PROBLEMS

Kuntal Som

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Bilevel programming is one of the very active areas of research with many real life applications in economics and engineering. Bilevel problems are hierarchical problems, consisting of lower level and upper level problems, respectively. The leader, or the decision maker for the upper level problem decides

first, and then the follower, or the lower level decision maker choose his/her strategy. In case of multiple lower level solutions, the bilevel problems are not well defined and there are many ways to handle such a situation. One standard way is to put restriction on the lower level problems (like strict convexity) so that the non uniqueness does not arise. However, those restriction are not viable in many situations. Therefore there are two standard formulations, called pessimistic formulations and optimistic formulations of the upper level problem. A set-valued formulation has been proposed and studied in the literature as well. However those have been studied only under continuity assumption of the objective functions. In this work, we focus on the most general case and compare among various formulations.

21_44 A Modified q-BFGS Algorithm for Unconstrained optimization

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There are several methods for solving minimization problems. Many of them are variations of the Newton method that require the specification of a Hessian, but the quasi- Newton method uses only the q-gradient to approximate the Hessian over some iteration. BFGS method is most efficient among all quasi –Newton method. In this paper, we present a modified q-BFGS Algorithm for solving nonlinear unconstrained optimization problems. For this modification, we first propose a new q-quasi-Newton equation. In this new modification, we take the help of the q-Taylor formula and some second-order information from the q-Hessian matrix of the objective function. This modified q-BFGS algorithm prove to possess global convergence property without the convexity assumption on the objective function. The proposed algorithm has been tested numerically which shows that the modified algorithm is more effective.

22_45 On Zero-Sum Two Person Perfect Information Stochastic Games

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In this paper we consider a zero-sum two-person perfect information stochastic game (PISG) under limiting average payo_, where one of the players has exactly one action in each state. We prove that this game has a value and both the maximiser and the minimiser have optimal pure stationary strategies. Liggett and Lippman previously proved the existence of pure stationary optimal strategy pair of the players in an undiscounted perfect information stochastic game. We propose an alternative proof (with less complexity) of the result by Liggett and Lippman by forming the matrix of undiscounted payo_s

corresponding to each pair of pure stationary strategies (for each initial state) of the two players and proving that this matrix has a pure saddle point. Then we prove the existence of optimal pure stationary strategy pair of the players by using the results by Derman. We consider the policy-improvement algorithm to compute optimal pure stationary strategy pair of the players. This is a best response algorithm, in which each player looks for his own Blackwell optimal strategy. It is obvious that this is a finite step algorithm and it terminates in finite time by the conjecture 8:1 of Raghavan and Syed (2002). We also construct some numerical examples to establish our claim.

23_46 Trust region strategy for the nonconvex constrained multi-objective optimization problems

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In this paper, a numerical approximation method is developed to find approximate solutions to a class of constrained multi-objective optimization problems. All the functions of the problem are not necessarily convex functions. At each iteration of the method, a particular type of subproblem is solved to obtain the descent direction, and the trust region step is eval uated using the notions of actual reduction and predicted reduction. A non-differentiable l∞ penalty function is used to restrict the constraint violations. An adaptive BFGS up-date formula is introduced. Convergence of the proposed algorithm is established under the Mangasarian-Fromovitz constraint qualification and some mild assumptions. Furthermore, it is justified that the proposed algorithm displays a super-linear rate of convergence. Numerical results are provided to show the efficiency of the algorithm in the quality of the approximated Pareto front.

24_47 Combating the outbreak of the COVID pandemic: A study using a two- stage leader-follower DEA model

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As the pandemic caused by SARS-CoV-2 throughout the globe resulted in an unprecedented loss in terms of human lives and national economies, the need for a robust and coordinated containment strategy was becoming even more acute. Different quick response teams such as disaster management, local administrative bodies, and healthcare systems are fighting this multi-frontier war to the best of their

capacities. However, this paper studies the benefits of having a closely coordinated approach toward containing the adverse impact of the outbreak. Data Envelopment Analysis (DEA) has been used to model the production function and prospective production possibilities to maximize the desirable outputs e.g., the number of people vaccinated and patient discharges, and minimizes the number of infected people and fatality. The proposed model deals with four different behavioural traits of the leader: Aggressive (tries to minimize follower's benefits), neutral (no concern for the follower), benevolent (maximizes the follower's benefits), and selfish (optimizes leader's exclusive outputs). We have further quantified the level of sacrifice made in terms of the output values if the leaders change their behavior.

25_48 Minty Variational Principle for Nonsmooth Interval-Valued Vector Optimization Problems

B.B. Upadhyay and **Priyanka Mishra**

In this chapter, we consider a class of nonsmooth interval-valued vector optimization problems and a class of approximate Minty and Stampacchia vector variational inequalities. Under generalized approximate LU-convexity hypotheses, we establish the relations between the solutions of approximate Minty and Stampacchia vector variational inequalities and the approximate LU-efficient solutions of the nonsmooth interval-valued vector optimization problem. The results of this chapter extend and unify the corresponding results of Mishra and Upadhyay (2013), Mishra and Laha (2016), Zhang et al. (2016), Upadhyay et al. (2017) and Gupta and Mishra (2018) for nonsmooth interval-valued vector optimization problems.

26_50 Nonlinear enhanced interval fractional programming problem

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This paper presents a non-linear fractional interval programming problem assuming the decision variables as closed intervals. The solution methodology of the model is described in two primary segments using the parametric perception of an interval. Initially, the original problem is converted into equivalent non-linear fractional interval programming with interval decision variables. Further, it is made free from interval uncertainty by transforming it into a classic non-linear programming problem by applying the concepts of multiple integral techniques. The solution's existence and justification are also explained. Finally, ahypothetical data numerical example is presented to support the model's recommended technique.

27_51 On Some Approaches to Find A Nash Equilibrium of an Oligopolistic Market by means of Nonlinear Complementarity Problem

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The paper aims to find a Nash equilibrium of an oligopolistic market through a suitable formulation of nonlinear complementarity problem. Here we consider an oligopolistic market structure for which n firms supply a homogeneous product in a noncooperative fashion. $P(\tilde{Q})$ at which consumers will purchase a quantity $\tilde{Q} \geq 0$, denotes the inverse demand function. Following generally accepted economic behaviour, this is assumed that $P(\tilde{Q})$ is strictly decreasing and the industry revenue curve $\tilde{Q}P(\tilde{Q})$ is a concave function of $\tilde{Q}$ for $\tilde{Q} \geq 0$. It is further assumed that $P(\tilde{Q})$ is continuously differentiable. Note that $\tilde{Q} = \sum_{i=1}^{n} Q_i$, where $Q_i \geq 0$ denote the ith firm's supply. $c_i(Q_i)$ is the total cost of supplying Q_i units. Now the Nash equilibrium solution is a set of nonnegative production levels $Q_1{}^*, Q_2{}^*, \cdots, Q_n{}^*$ for the n firms at which the market will be in a state of equilibrium, i.e. $Q_i{}^*$ is an optimal solution to the following problem for $i \in \{1, 2 \cdots, n\}$

$$\max_{Q_i \geq 0} \; Q_i P(Q_i + \tilde{Q}_i^*) - c_i(Q_i) \quad \text{where} \quad \tilde{Q}_i^* = \sum_{j \neq i} Q_j{}^*$$

In this connection we establish an equivalence between nonlinear complementarity problem and the system of nonlinear equations. We show that the solution of oligopolistic market ewquilibrium problem can be obtained by iterative method. We propose a continuation method with multiple parameters to find the solution of the system of nonlinear equations for which the continuous trajectory converging to the solution is smooth and bounded. In addition we consider Newton method to obtain the solution of system of linear equations to find Nash equilibrium and study Jacobian of the system of nonlinear equations to deal with its singularity. We introduce a modified Newton method with seventh order convergence to solve the same system of nonlinear equations. An example of oligopolistic market equilibrium problem is illustrated to show the effectiveness of the proposed algorithms.

28_52 Huberized twin support vector machine for binary classification problems

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Support vector machine (SVM) is one of the prominent machine learning techniques for classification and regression problems. It has been widely used in many real-world applications such as speech recognition, web-page recommendation, remote sensing and image classification. In comparison with the other methods, like multilayer neural networks, which minimize the training errors, SVMs were developed using the structural risk minimization technique, in which the upper limit on the classification error is minimized. As a result, SVM is unlikely to lead to overfitting. The standard SVM for binary classification uses the hinge loss function and aims to find the two bounding hyperplanes in such a manner that margin between these two planes is maximum.

Let $\{(x_i, y_i), i = 1, 2, \ldots, m\}$ is the training set for binary classification problem where x_i is the given training point and $y_i \in \{-1, +1\}$ is the corresponding output. SVM seeks a classifier $w^T x + b$ to separate the training pattern x_i according to the output class $y_i \in \{-1, +1\}$. The optimal classifier is obtained by solving the following optimization problem:

$$\underset{(w,b)}{\text{minimize}} \quad \tfrac{1}{2}\|w\|^2 + C\sum_{i=1}^{m} \phi_{hinge}(1 - y_i(w^T x_i + b))$$

where

$$\phi_{hinge}(1 - y_i(w^T x_i + b)) \begin{cases} 0, & \text{if } \ y_i(w^T x_i + b) \geq 1, \\ 1 - y_i(w^T x_i + b) & \text{if } \ y_i(w^T x_i + b) \leq 1, \end{cases}$$

and $C > 0$ is a trade-off parameter between the misclassification error and the margin.

The non-differentiability of the hinge loss function makes the problem difficult to solve the convex quadratic programming problems. Further, some authors presented SVM using huberized hinge

loss function (HSVM), the differentiable approximation of the hinge loss function. The elastic net regularization is emplyod to HSVM and the mathematical formulation to obtain the decision surface is given as follows:

$$\underset{(w,b)}{\text{minimize}} \quad \frac{1}{n}\sum_{i=1}^{n}\phi_H(y_i(b+x_i^T w)) + \lambda_1\|w\|_1 + \frac{\lambda_2}{2}\|w\|_2^2 + \frac{\lambda_3}{2}b^2$$

where $\lambda_1, \lambda_2, \lambda_3$ are regularization parameters and

$$\phi_H(y_i(x_i^T w_2 + b_2)) = \begin{cases} 0, & \text{if } y_i(x_i^T w + b) > 1, \\ \frac{\{1-y_i(x_i^T w+b)\}^2}{2\delta}, & \text{if } (1-\delta) < y_i(x_i^T w + b) \leq 1, \\ 1 - y_i(x_i^T w + b) - \frac{\delta}{2}, & \text{if } y_i(x_i^T w + b) \leq (1-\delta) \end{cases}$$

is the huberized hinge loss function, which is continuously differentiable. However, the condition of bounding planes to be parallel to each other restricts its application in many areas.
To address this issue, in this article we propose twin support vector machine with huberized hinge loss function (HTSVM) where the decision planes are non-parallel such that each plane passes through the corresponding class patterns and as far as possible from the patterns of other class. The huberized hinge loss function allows us to use an efficient and fastest first-order algorithm, proximal gradient method, for solving HTSVM. The proposed method regularize the model parameters to avoid overfitting. The elastic net penalty is employed in the proposed HTSVM, which is a combination of L_1 and L_2-norm penalty. In elastic net penalty, the purpose of the L_1-norm penalty is to enable feature selection, while L_2-norm penalty is used to select the correlated features together. The algorithm converges linearly since the objective function is the strong convex function. The proposed approach can deal with cross plane dataset and large dataset problems with less computational time as compared with the standard SVM and its variants. The experiments on real world datasets demonstrate that the proposed method has better estimation accuracy and effectiveness as compared to the existing methods. The Friedman and Nemenyi tests, are also used to make statistical conclusions which yields that the HTSVM is fast and offers better generalization, than the existing approaches.

29_54 The weighted vertical linear complementarity problem (wVLCP) on a Euclidean Jordan algebra

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This article deals with the weighted vertical linear complementarity problem (wVLCP) on a Euclidean Jordan algebra. For a pair of linear transformation, we analyse the existence and boundedness of solutions to the wVLCP by introducing the R_0', R' and P' pair property for a given pair. Also we give a uniqueness result to the wVLCP in Euclidean space $\mathbb{R}^n$. Finally, we give a relation between the wVLCP and weighted HLCP.

30_55 A new self-adaptive iterative method for variational inclusion problems on Hadamard manifolds with applications

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The objective of this article is to design an iterative method based on Armijo's type-modified extragradient method for solving the inclu- sion problem $(A+B)^{-1}(0)$, where A is a maximal monotone vector field and B is a continuous monotone vector field. A convergence theorem is established for the proposed extragradient method, which significantly improves existing results. We provide concrete examples of Hadamard manifolds and convergency for numerical confirmation. More- over, we demonstrate convergence results for the variational inequality problems in which the vector field's monotonicity can be removed.

31_57 A criterion for Q-tensors

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A tensor $\mathcal{A}$ of order m and dimension n is called a Q-tensor if the tensor complementarity problem has a solution for all $\mathbf{q} \in \mathbb{R}^n$. This means that for every vector $\mathbf{q}$ there exists a vector $\mathbf{u}$ such that $\mathbf{u} \geq \mathbf{0}, \mathbf{w} = \mathcal{A}\mathbf{u}^{m-1} + \mathbf{q} \geq \mathbf{0}$, and $\mathbf{u}^T\mathbf{w} = 0$. In this talk, we will discuss a criterion to determine whether a tensor is a Q-tensor. We prove that within the class of rank one symmetric tensors, the Q-tensors are precisely the positive tensors. We propose some necessary and/or sufficient conditions to determine whether a tensor is a Q-tensor. The idea is inspired by the recent work of Parthasarathy et al. and Sivakumar et al. on Q-matrices.

32_58 A hybrid clustering and greedy routing approach to solve a two-level location allocation and a static dial-a-ride problem

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Various optimization algorithms have been developed for generating feasible/optimal solutions of routing and clustering problems, separately, in the literature. Recent years have witnessed a surge in the development of these algorithms which is credited to globalization. Thus the transportation of goods, service and people from one place to another has increased to a large extent. The transportation of goods requires planning at two major levels, planning of the location of service centres and then planning of routes of service. So, this paper is concerned with the two-level modelling of the service set-up planning of a logistic service provider company. The problem discussed in this work is a combination of location allocation problem and a static dial-a-ride problem. The objective of the upper level decision maker is to decide the location of customer service centres in a city that maximizes the service coverage area and are located at prime locations in the city. The problem at the lower level comprises of a set of pickup locations and a corresponding set of drop locations for a given set of customers. The objective of the lower level decision maker is to design service routes for the customers. In this work, a solution methodology based on the combination of K-means algorithm and nearest neighbour approach is proposed to solve the proposed problem. To present the applicability of the proposed method, computational experiments are performed on randomly generated instances.

33_59 Mehar method for the solution of fully trapezoidal fuzzy linear programming models

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Akram et al. (Comput Appl Math (2022) 41:55) proposed a method to solve fully trapezoidal fuzzy linear programming problems (linear programming problems in which each decision variable and known parameter is represented by a trapezoidal fuzzy number). In this paper, it is pointed out that Akram et al.'s method can be used only if there does not exist subtraction in the objective function and in any of the constraints as well as each decision variable and known parameter is represented by a non-negative trapezoidal fuzzy number. Also, to overcome these limitations, a new method (named as Mehar method) is proposed to solve fully trapezoidal fuzzy linear programming problems. Furthermore, to illustrate the proposed Mehar method, a fully trapezoidal fuzzy linear programming problem is solved by the proposed Mehar method.

34_60 Modified matrix game-based approach for MADM with probabilistic triangular intuitionistic hesitant fuzzy information

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Yang and Xu (Computers & Industrial Engineering 163 (2022) 107787) proposed a new type of fuzzy set (named as probabilistic triangular intuitionistic hesitant fuzzy (PTIHF) set), an aggregation operator to aggregate PTIHF sets and a ranking function to transform a PTIHF set into its equivalent real number. Yang and Xu also proved that the linearity property is satisfying for their proposed ranking function. Using the linearity property of the proposed ranking function, Yang and Xu proposed a zero-sum matrix game based method to solve multi-attribute decision-making (MADM) problems under PTIHF environment. In this paper, it is shown that according to the arithmetic operations of PTIHF sets, considered by Yang and Xu to obtain their proposed aggregation operator, the linearity property is not satisfying for Yang and Xu's ranking function. Hence, according to Yang and Xu's arithmetic operations of PTIHF sets, Yang and Xu's zero-sum matrix game based method is not valid. Also, for the validity of Yang and Xu's zero-sum matrix game based method, new arithmetic operations of PTIHF sets are proposed. Furthermore, it is proved that according to the proposed arithmetic operations, the linearity property is satisfying for Yang and Xu's ranking function. Hence, Yang and Xu's zero-sum matrix game based method is valid only if the proposed arithmetic operations of PTIHF sets are considered instead of Yang and Xu's arithmetic operations of PTIHF sets.

35_61 Robust Linear Deviation Portfolio Optimization models and their Empirical Investigation.

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The traditional portfolio optimization models usually assume that the input data is accessible with certainty and ignores situations where input parameters are non deterministic which may leads to their unfavorable out-sample performance. More concretely, the input return data and the choice of the probability measure form the two primary sources of uncertainty in portfolio selection. Robust optimization overcomes this shortcoming by relaxing the assumption of the underlying distribution or parameter and gives a solution even if only partial information is available.

This work translates the three famous deviation risk measure based portfolio optimization models into their corresponding robust models under the worst case framework. We consider Semi-Mean Absolute Deviation (SemiMAD), Deviation conditional value- at-risk (DCVaR) and Deviation minimax (DMiniMax) risk measures due to their computational benefit (their corresponding models are linear programs). For all the three risk measures, we propose to develop their robust models under the three uncertainty sets namely, the mixed, the box and the ellipsoidal sets. The robust models of SemiMAD, DCVaR, and DMiniMax are found to be linear programs under the mixed and box uncertainty sets whereas they are second order cone program under ellipsoidal uncertainty set.

The empirical investigation is proposed to carry over seven global market data sets, namely, S&P500, CNX-100, DAX-100, DOWJONES, FTSE-100, NASDAQ-100, NIFTY-50 from the period of 10 years from 2012 to 2022 using rolling window scheme. With the aim of finding out the best combination of deviation risk measure with the uncertainty set, we first propose to compare all robust models formed corresponding to the three risk measure for one fixed uncertainty set and secondly, we compare robust models formed corresponding to three uncertainty sets for one fixed risk measure. Our numerical findings from the data set S&P500, we observe that for the fixed mixed uncertainty set, robust SemiMAD model works well in terms of mean return, Sharpe ratio, STARR ratio and Sortino ratio than their robust counterparts DCVaR and DMiniMax whereas the robust DCVaR performs well in terms of risks. On the other hands, for the fixed model say SemiMAD, we observe that the robust SemiMAD under Mixed case outperforms both of its robust counterparts uncertainty wise, i.e. the robust SemiMAD under box and the robust SemiMAD under ellipsoidal unceratinty sets, in terms of mean return and ratios (Sharpe, STARR, Sortino).

36_62 Economic Analysis of Discrete-Time Geo/Geo/1 G-Queue with Multi-Optional Services and Bernoulli Feedback

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The present study investigates discrete-time Geo/Geo/1 G-queue with an unreliable server, k-optional services, and Bernoulli feedback. We consider both positive and negative arrival of customers, and the arrival of a negative customer takes away a customer in service, which causes the failure of the server. Also, we consider that all arriving customers must take the first essential service (FES). After FES, the customers desire further services in which they may choose any one of the k-optional services or may join the queue again to take another FES, and if they do not want to take these further services, they can leave the system. Matrix-geometric approach is employed for queueing analysis and to derive steady-state probability, the expected number of customer in the system, throughput, and average delay. A cost model is established, and the Quasi-Newton method and Particle swarm optimization technique are employed to achieve optimal operating conditions with minimal expected cost.

37_63 Sequential Malmquist-Luenbeger Productivity Index for Interval Data Envelopment Analysis

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Data envelopment analysis (DEA) based productivity index models are widely applied to evaluate the productivity of decision-making units over a period. This study proposes a productivity index for evaluating environmentally sensitive productivity growth while excluding the possibility of spurious technical regress. This innovative index has been created by combining directional distance functions, sequential DEA, undesirable data, and the concept of interval DEA. With this combination, the traditional sequential Malmquist- Luenberger productivity index (SMLPI) has been reformulated as an interval DEA problem to present a novel productivity index named

interval SMLPI. We propose a decomposition of the developed index utilizing both constant returns to scale and variable returns to scale frontiers as the benchmark, which allows us to quantify scale efficiency change with interval data. To exhibit the capability of the proposed extension of SMLPI, we model a framework for Indian commercial banks and measure productivity change intervals for twenty-one banks from 2011 to 2018. The empirical findings elucidate that the scale efficiency change plays an essential role in driving productivity change. ICICI Bank had the highest average marginal productivity gain of 1.5007 between 2011 and 2018, whereas Karur Vysya bank had the highest average marginal productivity decline of 0.9411.

38_64 Multi- Objective Integer Quadratic Fractional Programming Problem

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The aim of the paper to develop a method for solving a multi-objective integer quadratic fractional programming problem (MIQFP). As quadratic fractional function is not quasi-monotone, a vertex search technique can't be used to solve it. For solving the problem (MIQFP), we have constructed a linear fractional function (or linear function), which provides a lower bound to an objective of the problem (MIQFP). In the developed method, we have utilized successive optimization of an integer linear fractional programming problem (or integer linear programming problem) for finding the set of all efficient solutions of the problem (MIQFP). The proposed methodology is simple to implement as it finds the efficient set of problem (MIQFP) by solving an integer linear fractional programming problem (or integer linear programming problem) iteratively. The convergence of our algorithm is established theoretically and numerical examples are also included in this paper to elaborate the working of the proposed algorithm. Further, using numerical examples we have done comparative analysis of the proposed method with existing methods. The particular case of the proposed algorithm for solving a multi-objective integer linear fractional programming problem is also discussed.

39_69 Worst-case analysis of Omega-VaR ratio optimization model.

Ruchika Seghal1, **Amita Sharma2**, Renata Mansini3

The Omega ratio, a performance measure that separately considers upside and downside deviations from a fixed threshold, improves the Sharpe ratio by incorporating the higher-order moments. In this study, we analyse the performance of a robust optimization model based on maximizing the worst-case of Omega ratio by taking its threshold point as the worst-case value of VaR (WVAR) computed at an (1-α) confidence level of the underlying loss distribution. Using a VaR measure has some advantages, including the possibility to select, for the Omega ratio, a more meaningful threshold value expressed as a defined percentile of the loss distribution and simply defined and controlled through parameter α.

We formulate robust model of the proposed strategy under two cases of uncertainty sets, the mixture distribution uncertainty and the box uncertainty. The main reason for taking WVaR instead of nominal VaR is to have a robust value for the threshold point. Moreover, the problem minimizing the WVaR measure reduces to convex programs for both the cases of the box and mixture distribution type of uncertainty sets, whereas this is not true with VaR.

We show that, the proposed model reduces to a second-order cone program (SOCP) in the case of mixture distribution case and it becomes a semi-definite program (SDP) in the case of box set and hence tractable in both the cases. We conduct a comprehensive empirical investigation of the proposed models over six data sets across the globe, namely BSE 100 (India), FTSE 100 (UK), Hang Seng (Hong Kong), S&P Asia 50 (Asia), Dow Jones Industrial Average (USA), and IBEX (Spain).

We compare our models with the three variants of the Omega ratio model, one its robust variant taking worst-case conditional value-at-risk as threshold point, and two of its nominal variants using value-at-risk and conditional value-at-risk as threshold points, respectively. We find that the proposed model red under mixture distribution uncertainty exhibits a better performance over most of the data sets and scenarios than its CVaR-based robust counterpart. Under the box set, the proposed model performs similar or generates mixed results compared to its CVaR-based robust counterpart model. We also note that both the proposed robust models save investors against the risk of losses over the bearish phase of market in comparison to their nominal counterparts. Finally, on comparing the proposed model under mixture distribution uncertainty with the box uncertainty, the former model is found to be more suitable for optimistic investors, whereas the later strategy is more ideal for pessimistic investors.

40_70 Optimality conditions and duality analysis for a class of conic semi-infinite optimization problem having vanishing constraints

Tamanna Yadav1 and S. K. Gupta1

This work concentrates on a non-smooth conic semi-infinite optimization model having vanishing constraints. Firstly, a necessary optimality condition for the optimization model is developed using the limiting constraint qualification. Then, the concept of generalized convexity over cones is introduced and sufficient optimality conditions are developed. Further, Wolfe's and Mond-Weir type dual models are formulated for the considered semi-infinite optimization problem, and weak, strong and converse duality results are established under generalized convexity/ pseudoconvexity/ quasiconvexity assumptions. Moreover, to justify the results, numerical illustrations have also been shown at suitable places.

41_ 72 Optimization of Fuzzy Transportation Problem using New Ranking approach with Fuzzy Numbers

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Transportation problem plays an important role in the Human society, industries and other activities. Economically, Transportation is responsible for an important part of the country's gross national product. A special form of linear programming known as the transportation issue allows for the control of the ideal shipping route between origins and destinations.

Decision-making problems, data analysis, and socioeconomic systems all highly depend on ranking fuzzy numbers. Numerous mathematical models require that fuzzy numbers be ranked. Most of the approaches that have been suggested so far don't discriminate. In this work, the fuzzy transportation problem is changed into crisp valued transportation problem (TP) using a novel ranking mechanism. Then crisp valued transportation problem is solved by Vogel Approximation Method (VAM) with TORA Software to obtain the fuzzy optimal solution. It can be seen from numerical examples of Triangular fuzzy number, Pentagonal Fuzzy Number and Hexagonal Fuzzy Number that the fuzzy ranking method provides a powerful tool that addresses fuzzy transportation problems.

In the present work, the fuzzy transportation problem has been optimized using the following ranking approach for fuzzy numbers.

42_74 Metaheuristic Optimization and Joining Strategies for Broken-Down of Retrial Queue

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This research investigates the strategic behavior of a stochastic model that accounts for the broken-down of regular customers (RCs) with constant retrial queues. Regular customers (RCs) and primitive customers (PCs) can join or balk depending on the trade-off between service profit and delay cost. Furthermore, due to the overcrowding of RCs, the server may terminate due to broken down. Two

categories of strategies have been considered in this research work for customers' joining, i.e., a non-cooperative strategy where customers aim to optimize individual interests, and the social planer in the cooperative strategy has considered the profit of the whole service system. The probability-generating functions of the system size, throughput, and other performance indices are explicitly established. The cost optimization is examined numerically through the particle swarm optimization technique. Statistical analyses are done such as best fitness, average fitness, classification accuracy, standard deviation (SD), elapsed time, and drawing convergence. Finally, we present extensive validation results based on realistic simulation scenarios.

43_75 MIXED VARIATIONAL-LIKE INCLUSION INVOLVING YOSIDA APPROXIMATION OPERATOR IN BANACH SPACES

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This paper deals with the study of mixed variational-like inclusions involving Yosida approximation operator (MVLIYAO) and η-proximal mapping in Banach spaces. It is investigated that (MVLIYAO) is equivalent to fixed point problems in Banach spaces. Using this equivalence a new iterative algorithm is proposed to find the solution of (MVLIYAO). A numerical example is provided to support our main result by using the MATLAB program.

44_ 77 Extended Mean expectile-based VaR portfolio model for short selling scenarios by incorporating l1-norm and turnover constraints

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An expectile is a statistical functional defined as the minimizer of an asymmetric quadratic loss function. Owing to its unique property of being both coherent and elicitable, expectile has recently been explored as an alternate measure of risk to value-at-risk (VaR) and conditional value-at-risk (CVaR). Analogously, as a risk measure, it is defined as expectile-based value-at-risk (EVaR). This study proposes to extend the mean expectile-based VaR portfolio optimization model to incorporate short selling strategy. To assimilate different practical arrangements of a short-sale transaction, we analyze several constraints such as proportional bounds, l_1-norm constraint, bounded budget, and turnover constraints. We conduct extensive in-sample and out-of-sample analyses using historical data of the stocks listed in the CNX NIFTY 50 (India), HangSeng (Hong Kong), FTSE 100 (UK), and DAX 100 (Germany) indices over a period of ten years using a rolling

window strategy. While the l_1-norm constraint and the bounded budget help to restrict the total short-sale budget, the turnover constraint helps in tuning the portfolio turnover, thereby reducing the overall transaction cost. The empirical results highlight the benefits of choosing specific constraints to assist practical decision-making for the short-selling strategy in the proposed model. We further compare our proposed model with its closely related model based on CVaR under a similar setting and observe the financial benefit of our model for most of the cases.

45_78 On approximate vector variational inequalities and vector optimization problem using convexificator

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In the present article, we study a vector optimization problem con-taining locally Lipschitz-approximately convex maps in terms of convexificator and give some ideas for approximate efficient solutions. In terms of the convexificator, we approximate Stampacchia-Minty type vector variational inequalities and use them to describe an approximately efficient solution to the nonsmooth vector optimization problem. Moreover, we give a numerical example that attests to the credibility of our results.

46_79 Optimization of Multi -Echelon Reverse Supply Chain Network Using Genetic Algorithm

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Remanufacturing of items adopted by various companies in recent time due to environmental issue, and the close loop supply chain network as a part of optimization of reverse logistic system. The goal of present research is to find the best close loop supply chain (CLSC) network, which includes number of producers, remanufacturers, intermediary centres, and client centres. To achieve the objective of the work, considered multi-product, multi-echelon closed loop supply chain network model for returns product, where material acquisition, manufacture, distribution, recycling, and disposal decisions play major role. A mixed-integer linear programming (MILP) model which minimizes total cost (TC) is also taken to solve the problem. A Genetic Algorithm (GA) is used to solve the objective based numerical problem to validate the proposed method and find the best results to deliver certain products with its minimum cost for each distribution centres (DCs) of these supply chain network.

The genetic algorithm is one of the most advanced feature selection algorithms. The genetic algorithm begins by forming a set of potential solutions known as populations, where the initial population generation was done at random. There are individuals of the population called chromosomes. This algorithm operates on a population of individuals to improve approximations over time.

Manufacturers have been attempting to remanufacture and reuse their products in recent years in order to prevent pollution caused by end-of-life products due to environmental concerns. A facility location optimization challenge in a CLSC network has been proposed in recent study. Customer centres, intermediate centres, producers, and remanufacturers are all a component of the imagined CLSC network. In this paper, we presented a mixed integer linear programming model (MILP) to optimize multi-echelon multi product supply chain network using genetic algorithm (GA). The present work may be extended to an optimization of closed loop supply chain logistics under time constraint, price fluctuations for various Products etc.

47_81 The event-triggered consensus problem of non-linear multiagent systems

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In this paper, the event-triggered consensus problem of non-linear multiagent systems with time-varying communication delays and random packet losses are addressed. An event-triggered controller is proposed to eliminate unnecessary usage of communication resources and a novel periodic switching controller is developed to avoid the asynchronous phenomenon caused by communiaction delays. For random packet losses, a Bernoulli-distributed white sequence is used to describe packet dropouts among agents in a stochastic way. Furthermore, a new criterion based on linear matrix inequalities (LMIs) and Lyapunov-Krasovskii functional (LKF) are constructed for the exponential stability of the consensus error system. Finally, an illustrative example is presented to demonstrate the advantages of the developed method..

48_82 2-person nonzero sum unbalanced linguistic games

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This study proposes a novel concept of 2-person nonzero sum games having payoffs as unbalanced linguis-tic terms. Such games have payoffs belonging to a predefined multiplicative unbalanced linguistic term set defined in the domain $[a^{-n}, a^m]$, where $a > 1$, $n, m \in \mathbb{Z}^+$, having cardinality $n + m + 1$. In this direction, the concept of 2-person nonzero sum unbalanced linguistic games is first defined, and a methodology is then provided to solve this class of games. This methodology offers the solution to such games by computing the Nash equilibrium and the expected payoffs of both the players simultaneously. It is demonstrated that the necessary and sufficient condition for a point to be a Nash equilibrium of a 2-person nonzero sum game with a finite number of pure strategies, is equivalent to solving a single programming problem with linear constraints and a quadratic objective function with a global maximum of zero. The problem of linguistic information is transformed into a mathematical problem that can be solved quickly, which reduces the uncertainty and complexity caused by linguistic information.A numerical example is used to demonstrate the efficacy of the suggested methodology.

49_83 A novel hierarchical model is proposed based on the architecture of LTE-A network.

Anupam

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The Long Term Evolution Advanced (LTE-A) is a standard for a high-speed wireless communication of mobile devices and data terminals. In the world of broadband network, LTE-A is facing a large demand due to its high-speed wireless data transmission, extensive coverage from base stations, and a luxury of upgrading protocol software. However, factors such as, hardware and/or software failure and power supply outage due to antenna tilt, software bugs, environmental changes, etc., can be the reasons behind network system's inefficiency. Therefore, efficiency of LTE-A depends mainly on the two significant attributes which are reliability and survivability. Further, the prospects of these attributes are mainly depends on the LTE-A architecture and its network.

In this work, a novel hierarchical model is proposed based on the architecture of LTE-A network. It is further classified into the upper level and lower level models. Upper level models are Reliability Block Diagrams(RBDs) whereas lower level models are continuous time Markov chains. This classification is performed to capture a realistic approach towards modeling because dependent behavior and repair of failed components,etc., are not taken into account by an RBD model. Performance metrices such as, reliability, availability and survivability are are analyzed numerically.

50_84 CONNECTEDNESS OF THE SOLUTION SETS IN GENERALIZED SEMI-INFINITE SET OPTIMIZATION

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A class of vector optimization problems which comprise of finite n umber o f d ecision v ariables and infinite number of constraints are referred to as semi-infinite vector optimization problems. In this work, we introduce generalized semi-infinite set optimization problems as a natural extension of the generalized semi-infinite vector optimization problems.

We first give sufficient conditions for arcwise connectedness of the image of the constraint set map and for upper semi-continuity of the constraint set map. These results, together with scalarization techniques, are further used to establish the connectedness of the solution sets of generalized semi-infinite set optimization problems. We also give an application to vector-valued game theory with uncertainty.

51_86 Generalized Hukuhara ε-subdifferentiability for interval-valued functions and its applications in nonsmooth optimization

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A problem is called an interval optimization problem if it is associated with the interval-valued function. Due to the uncertain nature of many real-world occurrences, the study of interval optimization problems has become a noteworthy research topic. Commonly, real-world problems are nonsmooth in nature. To handle these types of problems, the concept of subdifferentiability is used often. However, there are many interval optimization problems whose exact solutions cannot be found. These problems cannot be solved by using subdifferentiability. In this study, to find approximate solutions to such problems, we propose the notion of ϵ-subdifferentiability for convex interval-valued functions with the help of generalized Hukuhara difference. Several important characteristics of ϵ-subdifferential set, such as nonemptiness, closedness, convexity, boundedness, etc., are given in this study. Furthermore, a new solution concept, namely approximate solution or ϵ-solution, is introduced for an interval optimization problem. Using the proposed ϵ-subdifferentiability, we develop two necessary and sufficient optimality conditions to find an ϵ-solution for an unconstrained interval optimization problem. Lastly, a theorem has been given to solve interval minimax optimization problems using ϵ-subdifferentiability. Some numerical examples are also presented to support the whole study.

52_87 Analysis of Extended Karush Kuhn Tucker type conditions in Interval Optimization Problems with the help of generalized Hukuhara subdifferentiability and the Nonconvex Nonsmooth Composite Model in Interval Optimization

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The study of variational analysis includes problems based on well-posedness, sensitivity, and stability. With the development of quantum mechanics in atomic and subatomic physics, several methods were adopted during the 20th century to estimate the changes observed in a particle with the emission in radioactive elements. Several theories and methods have been developed for finding an approximate solution to a perturbed problem. This includes proposing the optimality conditions in various problems of optimization and equilibria, viscosity solutions of partial differential equations, etc.

In this talk, firstly, we discuss the calculus for gH-subdifferential of convex interval-valued functions (IVFs). Next, with the help of developed results, we analyse a Fritz-John-type and a Karush-Kuhn-Tucker-type efficiency condition for weak efficient solutions of IOPs. Thereafter, we apply our developed theories in a nonconvex nonsmooth composite model of an interval optimization problem (IOP). To support our results, we perform a comparison of our theory with the existing Karush-Kuhn-Tucker and Fritz-John conditions for IOPs. After that, we report a characterization of the weak efficient solutions of the nonconvex nonsmooth composite model by applying the proposed concepts. Finally, we present applications of developed results on the nonconvex nonsmooth model in 'Convex constrained nonconvex programming problems' for interval optimization problems (IOPs) and in 'Lasso optimality conditions' for interval optimization problems (IOPs).

53_88 Solving Uncertain Multiobjective Optimization Problems using the Cone Method with Minmax Robustness

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It is often hard to find optimal solutions to real-world optimization problems, which is due to the uncertainties that can deteriorate the quality of an optimal solution or even render it infeasible. Robust optimization, which aims to find solutions that are feasible for all possible scenarios of uncertain input data, is one way of dealing with uncertainty. For problems with a single-objective function, robust optimization has been very well developed to address decision-making under uncertainty. Typically, most real-world decision making problems have multiple decisions or goals. Therefore, researchers have recently acknowledged the necessity of finding robust solutions to multiobjective problems and presented some preliminary results on this subject.
In this talk, we extends the use of the cone method for robust multiobjective optimization problems. Next, we propose the robust counterpart of an uncertain multiobjective optimization problem and analyse the concept of robust efficiency for uncertain multiobjective optimization problem. Further, we describe an interpretation of robust counterpart of an uncertain multiobjective optimization problem using the idea of objective-wise worst case.
The applicability of our proposed work can be seen to obtain all the robust efficient solutions of an uncertain multiobjective optimization problem having robust counterpart which may not be possible by the implementation of weighted sum and ϵ-constraint methods. The primary reason that supports the recommendation of the cone

method for uncertain multiobjective optimization problems is its appropriacy for deterministic non-convex optimization problems. If the robust counterpart of an uncertain multiobjective optimization problem is non-convex, then the cone method may be a better alternative than other existing scalarization methods.

54_89 A new multi-attribute group decision-making approach under triangular Pythagorean fuzzy environment

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Triangular Pythagorean fuzzy numbers (TPFNs) are more effective at modelling fuzzy real-world problems. The goal of this paper is to present a multi-attribute group decision making (MAGDM) technique in a triangular Pythagorean fuzzy environment where decision-makers' (DM's) inputs have been collected in the form of TPFNs to better capture the uncertainty of the real-world scenario. The correlation consensus degree has been calculated to determine the weights of DMs. The correlation between a particular DM's judgment and collective judgement has been calculated to determine how much any individual judgment resembles the collective judgement and accordingly weights have been allocated to the DMs. Dombi aggregation operators (DAO) which are known for demonstrating the advantage of good flexibility with the operational parameter, have been developed in the triangular Pythagorean fuzzy environment for information fusion. Furthermore, the operator introduced, namely triangular Pythagorean fuzzy Dombi aggregation operator's (TPFDA's) properties are described. In order to determine the criteria weights, preference and non-preference of one criterion over other are expressed in terms of the strength and weakness scores based on the advantage and disadvantage scores, respectively. An optimization model is developed for maximizing the overall satisfaction degree utilizing the strength and weakness scores. The methodology has been applied for the very demanding site selection problem of solar photovoltaic (PV) cells for the state of India. Some more analyses have been performed to demonstrate the effectiveness of the methodology developed.

55_92 Designing and conditioning basis set as memory function for image reconstruction

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Signal reconstruction mainly involves the recovery of the original signal from a sequence of sampled signals. There are many and varied real-life applications where signal reconstruction plays a vital role, one such example is the domain of medical imaging. There are various techniques for sampling the signals and identifying a map that will allow the signal to be either perfectly or almost perfectly reconstructed. Finding such a map can be done in different ways. The best approach is to use a reconstruction method that produces the least amount of expected error variance. The challenge with such an approach is that a-priori information about the signal statistics or a-prior probability for the signal is required. For most of the real-life applications, having or defining such a-priori statistical knowledge is practically impossible. Another way to design a reconstruction algorithm is to first choose some reconstruction formula and then analyze how to sample the signal.

In this work, we propose an approach to establish a linear map between the sampled data and the reconstructed signal in such a way that the linear map behaves as memory function. The defined memory function can be used again and again for reconstruction of similar objects. The major advantage of defining such a memory function will help in reducing the acquisition of sample data. There are many real-life applications, especially in medical imaging and biometrics, where we need to reconstruct the similar objects with subtle changes again and again. In such scenarios, it is important if those subtle variabilities can be captured as samples for the first time and then can used it again and again instead of sampling the complete object. In this mathematical framework, we are violating the concept of regular acquisition of the samples and the signal processing approaches, popularly known as Nyquist sampling. This violation allows us to construct our reconstruction problem as a linear system of equations in many real-life applications. Once we have linear system of equations, i.e., $y=Ax$, where as $y \in R_M$ is sampled data, $x \in R_N$ is the reconstructed image. In general, $M \ll N$,*i.e.,* dimension of sampled data vector is very less then dimension of the reconstructed image vector. Solving such a linear system of equations as a reconstruction problem is a challenging problem and has been addressed in past by many researchers. We only have sampled data, i.e., $y \in R_M$ and we need to estimate $x \in R_N$ as best as possible. The complete theory of compressive sensing is based on estimating the system matrix A in such a way that we achieve perfect or almost perfect reconstruction, i.e., best possible estimation of reconstructed image $x \in R_N$. Our proposed work is inspired by the well-established concepts of compressive sensing and perfect reconstruction but we are attempting to estimate the system matrix A such that it works as a memory function for the future reconstruction of similar objects. So far to best of our knowledge no such result has been discussed or shown in literature. The advantage of such mathematical framework will allow us to acquire minimal samples of the object and reuse the system matrix A for image reconstruction in future as

well and with less samples. Our attempt is also to establish sufficient condition for the minimum sampled data size to be acquired for subsequent reconstructions.

To establish the mathematical framework, initially we have chosen computer tomographic (CT) image reconstruction application. CT image reconstruction is one of the most vital medical imaging modality. There are multiple scenarios where a patient has to go multiple times for scanning through CT machine. Such scenarios perfectly fit to our proposed approach of image reconstruction. Currently, we are successful in establishing the basic results using the phantom data for 2D image reconstruction. In future we plan to show our results for real data for 3D image reconstruction and also to explore the other real-life applications and to establish full proof mathematical framework.

56_93 Multi-attribute group decision making using projection measure in interval-valued q-rung orthopair fuzzy environment

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In this paper, the COPRAS (Complex Proportional Assessment) method is extended for interval-valued q-rung orthopair fuzzy numbers (IVq-ROFNs) to solve multi-attribute group decision-making (MAGDM) problems. A novel distance measure for IVq-ROFNs is proposed, and its properties are also probed. This distance measure is used in an improved weights determination method for decision-makers. A weighted projection optimization model is developed and used to assess completely unknown weights of the attributes. The projection of assessment values is defined by the positive and negative ideal solutions, which determine the resemblance between two objects by considering their directional angle. Thus, the weights obtained through the proposed approach are more reasonable and can better cover the decision-making uncertainty. An Indian cities' ranking problem for a better solid waste management infrastructure is solved using the proposed approach based on composite indicators, like recycling waste, greenhouse gas emissions, waste generation, landfilling waste, recycling rate, waste to energy rate, and composting waste. Numerical comparisons, sensitivity analysis, and other relevant analyses are performed for validation.

57_95 A Derivative free Descent Method for Solving Set Optimization using Oriented Distance Function

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In this presentation, a descent method is proposed for solving a set optimization problem. We consider the following set optimization problem

$$\begin{array}{lll} \text{(P)} & \text{Minimize} & F(x) \\ & \text{subject to} & x \in X. \end{array}$$

where $F : X \rightrightarrows Y$ is a K-convex set-valued mapping and X, Y are real normed linear spaces. Kuroiwa [1,2] considered various set order relations for comparing sets and to define solution concepts based on t hem. In set optimization, scalarization is a widely used technique for comparing the sets while using descent algorithms. Various scalarizing functions are used to characterize the set order relations. We consider the solution concept based on one of the set order relation, namely lower set order relation and use the oriented distance function to provide a scalar characterization of the set order relation. In particular, we provide the characterization of polyhedral sets in terms of oriented distance function. We also characterize lower set order relation with respect to polyhedral cones. Using the scalar characterization a descent method is developed where descent direction is computed using derivative free approach and follow the classical backtracking procedure of Armijo's like rule for the line search. Some numerical examples are also presented to illustrate the performance of the method.

58_96 Dependability Analysis of High Altitude Platform Station Using Stochastic Modeling Approach

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High Altitude Platform Station (HAPs) is a network node that functions at an altitude of around 17-20 km in the stratosphere. It plays a crucial role in the provision of communication services. Providing cellular connections via HAPS is a creative solution to address the drawbacks of both terrestrial tower-based and satellite systems. To offer coverage and capacity, several HAPs systems come together to form a network which is considered to be a integrated HAP network system.

The main aim is to develop and study methods for reliability modeling and relia-bility enhancement of high altitude platforms. An analytical model is developed for the Integrated HAPs network architecture to obtain its dependability at-tributes such as availability, survivability and reliability. To determine dependability attributes, a variety of stochastic modelling techniques, including Con-tinuous Time Markov

Chains(CTMC) and Reliability Block Diagrams(RBD), are used. A three-level hierarchical model is proposed to obtain these depend-ability attributes. This model is classified into the upper level and lower level models. Upper level models are CTMCs whereas lower level models are RBDs. At lower level, all the HAPs in the range of transmission are considered to be equipped with identical Ground Station. The System reliability is dependent on the number of HAPs that are active in the group of HAPs in the range of transmission of the Ground Station. Ground Station is connected in series with all HAPs. It is going to be assumed that failure and repair rate of all components of ground station and HAPs follows Exponential distribution. At upper level, a mathematical representation of a k-out-of-n system is considered that can be repaired and continues to function up until k of its n HAPs fail. The lifespan of the HAPs is assumed to follows Exponential distribution, while their repairs follows standard distribution. The hierarchical model is used to further examine these metrics numerically. The suggested model is validated using discrete event simulation, and numerical results are given visually.

The considered system's reliability characteristics and state probabilities were calculated and the results were obtained. The study of the acquired results demonstrates that there is good agreement between the simulation and analytical results.

59_98 Optimization of Multi-Objective Problem with Fuzzy Random Variable Using Revised Goal Programming Approach

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Goal programming approach is use for solving multi-objective optimization problem that is balance the trade-off in conflicting objectives of an organisation and decision makers. Due to increasing competition in the today's business environment, decision makers deal with the multi-objective optimisation under uncertainty. This paper proposes a new approach for optimisation of multi-objective problem using mean value of fuzzy random variable with revised goal programming approach. In this approach mean value fuzzy multi-objective programming algorithm is proposed and compare with modified simplex method of goal programming for best optimization solution. A numerical problem of three product and three unequal goals has been solved for validity of the models.

In the first algorithm we define the parameters of Fuzzy multi-objective programming problem and determine their mean value then convert to mean value modal called mean value fuzzy multi-objective programming problem. Zimmermann approach has been used to get so called M-optimal solution. This

solution is compared with the revised goal programming approach to get best solution. ur, Jaipur, Rajasthan, India.

60_101 Higher-order duality results for interval-valued problems with application

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In this paper, we study the class of higher-order interval-valued problems. In particular, the Mond-Weir type dual is introduced for the considered class. Further, a functional is analyzed which is higher-order invex but not invex. In addition to this, we theoreti-cally examined the primal and dual values under the assumptions of higher-order invexity. Numerical example has been illustrated to justify the efficiency of the proposed model. Additionally, a real-world example has been used to prove the weak duality theorem.

61_102 Development and Optimization of a Multi-Objective Closed Loop Supply Chain Mathematical Model by Integrating Economic, Environmental and Social Factors: A Case Study of Paint Packaging

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The Indian updated pledge to Paris agreement, also known as Nationally Determined Contribution (NDC), is to reduce its carbon emission intensity by 45% by 2030 from its 2005 levels. Roughly this means more than one billion tonnes of carbon emission reduction. The big question is who will bear the cost of this carbon emission reduction and what will be the effect on society. Businesses exists to maximize the shareholders money. Therefore, it is prudent to consider the economic, environmental and social aspects of businesses for a sustainable living. This requires a multi-objective model wherein economic, environmental and social factors will be optimized simultaneously. This paper aims to develop and optimize a multi-objective closed-loop supply chain model considering the economic, environmental and social factors. A case study of paint packaging has been carried out to validate the proposed model. Paint packaging is regarded as an important category of household waste; therefore, proper waste management and disposal become crucial when designing paint's entire value chain for sustainability. The proposed mathematical model is developed as a multi-objective mixed integer non-linear programming problem considering multiple customer zones, collection centres, multiple external suppliers, and different product recovery processes such as reuse, refurbishing, recycling, etc. The proposed model is solved using two methods; ε-constraint method to find Pareto solutions and global

criterion method to find the optimal solution. The python pyomo library and 'ipopt' solver is used to implement the solution methods. The Pareto solutions (frontier) represent the best trade-offs between the different objectives. The solutions on the Pareto frontier are non-dominated. From this study, we suggest that the paint drums recovery process (reuse, refurbish and recycling) is not only economically beneficial to the organization but also environment friendly and helps to create jobs for low skilled people.

62_103 Deviation Expectile-Mean Portfolio Optimization

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The expectile is a statistical measure that is defined as the minimizer of an asymmetric least squares loss function, mathematically for $\tau \in (0,1)$ expectile is given as: $e_\tau(X) = arg\min_{x \in R} E[\rho_\tau(X-x)]$, (where $\rho_\tau(x) = \tau x_+^2 + (1-\tau)x_-^2$, and $x_+ = max(x,0)$ and $x_- = (-x)_+$). As a risk measure, expectile is closely related to the other important tail risk measures, namely value-at-risk (VaR) and conditional value at risk (CVaR). Recently, many studies has been done on the minimization of expectile of a portfolio return due to its theoritical properties of being coherent and elicitable risk measure for $\tau \in [1/2, 1)$.

In this work, we aim to propose a deviation risk measure corresponding to the expectile i.e. expectile-deviation on the similar lines of deviation-CVaR. Deviation measure tells us how the portfolios perform against their mean returns. Mathematically, for a random variable X, deviation-expectile can be defined as $e_\tau(X-E[X])$, where $e_\tau(X)$ is the expectile of a random variable X for $\tau \in (0,1)$. Using the properties of expectile, we prove that expectile-deviation is also coherent and elicitable for $\tau \in [1/2, 1)$. We then propose a portfolio optimization model minimizing expectile-deviation risk measure.

We conduct an empirical analysis of the proposed model on the several global data sets and wish to compare its financial benefits with the closely related counterpart model minimizing CVaR-deviation under the similar setting.

63_104 Optimality Conditions for Nonsmooth Optimization Problems with Switching Constraints in terms of

Greenberg-Pierskalla Subdifferential

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In this paper, we consider a nonsmooth optimization problems with switching constraints. We derive nonsmooth Karush-Kuhn-Tucker (KKT) type necessary and sufficient optimality conditions for the nonsmooth optimization problems with switching constraints involving quasiconvex functions in terms Greenberg-Pierskalla subdifferential . We introduce several modifications of known constraint qualifications like Slater constraint qualification, Abadie constraint qualification, Mangasarian-Fromovitz constraint qualification and linear independence constraint qualification for the nonsmooth optimization problems with switching constraints in terms of Greenberg-Pierskalla subdif-ferential. We study the Wolfe-type dual problem and establish weak duality theorem and strong duality theorem for the above optimization problems.

64_105 Study of an inventory model for defective and deteriorating items having two production rates and stochastic demand in a finite planning horizon with permissible delay in payments

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An inventory production model is developed for deteriorating items out of which some items are produced defective. In this model, demand is considered stochastic and the demand follows the Wiener process. In this article, the planning horizon is considered finite, and shortages are considered negligible. And two production rates are assumed in this article. In this model, delay in payments by the manufacturer to the supplier is also considered. The model is solved and the optimal cost is calculated. A numerical example is solved and sensitivity analysis is done at the end. Change in variables is also discussed at the end.

65_108 Prediction of Reliability factors for Ceramic Tile Manufacturing System

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A manufacturing system's efficiency is determined by its numerous processes.Because failure entails significant financial losses.Success of any industry depends on the performance of its products or the manufacturing of those prod-ucts.The production of ceramic tiles is widely used in contemporary business, and every competitive industry seeks to learn how to enhance the quality and effective-ness of their own products.For this we want to manufacture product in that way that product has long time reliability. Boolean algebra technique is used for calculating varies of reliability factor.This systems consist eight subsystems viz Batching, Mixing and grinding, Spray drying, Forming, Drying, Glazing, Firing, Testing.Using these subsystems we construct a mathematical model of our plant.Graphical

assessment used to draw conclusions regarding the system cost and reliability. The concept of our result is verified by numerical examples.

66_111 Effect of Optimizers in Solving Differential Equations Using Deep Learning

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A deep learning model consists of inputs, outputs, activation functions, hidden layers, loss function etc. In deep learning, selecting an optimizer is a central step in order to minimize a loss function that measures the difference between the actual output and the predicted output. The optimizer updates the model's parameters like weights and biases iteratively in a direction that reduces the loss. The choice of optimizer and its hyperparameters can significantly affect the performance as well as training time of a neural network. In our paper, we demonstrated the sensitivity of different optimizers by applying them on a system of non-linear differential equations. The predicted and exact solutions of differential equations are analysed using deep learning by applying different optimizers like SGD, Adam, Nesterov, L-BFGS etc. It helps in analysing the effect of these optimizers to improve the convergence of the model and prevent overfitting.

67_112 Optimality and Duality for Geodesic Pseudolinear Programming Problem in Terms of Bifunction on Hadamard Manifolds

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In this paper, we consider a class optimization problems in-volving geodesic h-pseudolinear functions on Hadamard manifold. We derive necessary and sufficient optimality conditions for considered problem. Further-more, we formulate Mond-Weir type dual model related to considered problem and establish weak and strong duality results. The results derived in this paper generalize various well-known results from the literature to a more general space, namely, Hadamard manifold and extend to non-smooth optimization problems from smooth optimization problems.

68_113 Necessary and sufficient optimality conditions for interval-valued optimization problems

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In this paper, we consider a class of interval-valued optimiza-tion problems (in short, (IVOP)) and formulate associated scalar optimization problem (in short, (ASOP)). We establish that any minimizer of (ASOP) is an LU-solution of (IVOP). Moreover, we formulate a constrained optimization problem (in short, (ACOP)) related to (IVOP). We establish that every solution of (ACOP) is also a LU-solution of (IVOP). Furthermore, we establish neces-sary optimality conditions for (IVOP) by using continuous gH-differentiability assumption on the objective function. Moreover, we derive sufficient optimal-ity criteria for (IVOP) under strong convexity assumptions. Suitable numerical examples are provided to illustrate the derived results.

69, 116 Integrated Modelling and Analysing the Reliability of Industrial Process Fans

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Reliability studies are aimed at cost optimization. In the present work we consider distinct lifetime distributions such as Weibull Distribution and Fr´chet Distribution to model reliability of industrial process fans. Further we undertake composite assessment of mixture distribution vis-à-vis these elementary distribution with an objective of lifetime distribution to endorse the optimum distribution of lifetime distribution for future studies.

70, 119 Uncertainty in Multi-Objective Transportation Problems

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In general, transportation problem contains only one objective function for which optimal solutions can be obtained. But in real life scenario, it is required to deal with more than one objective function simultaneously, such as minimization of cost or distance or time or maximizing profit. This gives rise to multi-objective transportation problem (MOTP). In MOTP, different methodologies are applied by

decision makers to obtain the best compromise solution for the problem. Basically, we deal with transportation problems which has crisp values. Due to uncertainty in real life situations, MOTP is solved by researchers under distinct fuzzy environments. The uncertain framework for optimization of transportation problem depends on various aspects like inferior routes, fluctuating petrol/diesel prices, bad weather conditions etc. Here, a multi-objective transportation problem with fuzzy parameters (MOTPF) is studied under distinct environments. Different methodologies are applied to solve MOTPF, namely Pythagorean hesitant fuzzy programming approach (PHFP) and Intuitionistic fuzzy (IF) programming. Foremostly, under PHFP environment, Pythagorean hesitant decision set, objectives and constraints are presented. Accordingly, the membership and non-membership functions for each objective function of multi-objective transportation problem are defined. Thereafter, Pythagorean-hesitant fuzzy optimization problem is formulated in order to obtain the compromise solution for MOTPF using optimizing software's.

Further, MOTPF is studied under intuitionistic fuzzy environment. The intuitionistic fuzzy parameters, namely, cost, supply and demand are converted into interval form by applying α-cut and accordingly, a deterministic model is defined. The membership functions and non-membership functions for the objective functions are defined and then this problem is solved by intuitionistic fuzzy programming and goal programming approaches. The applicability of the proposed problem is exhibited through a numerical example which is then solved using LINGO software.

71_121 Bottleneck transportation problem over an efficient set of linear objectives

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The present study is in the context of a transportation problem that focusses on minimizing a bottleneck objective function over a set of efficient solutions corresponding to two linear objectives. In particular, the overall transportation time of a transportation problem is minimized over the set of efficient solutions corresponding to transportation and deterioration cost of the homogeneous product that is being transported.

In this paper, we develop an efficient ranking technique that finds the Pareto front in the criteria space of the problem and minimizes the bottleneck objective over this. The optimal objective value lies on one of the vertices of the underlying polyhedral feasible region. The algorithm starts by finding anchor points of

the Pareto front and obtaining the corresponding objective values. Then, the algorithm sweeps the whole criteria space in search of all the Pareto optimal solutions by starting from one of the relevant anchor points and then ranks these solutions in a particular manner. The algorithm converges in a finite number of steps . Numerical and computational experiments are included to elaborate the working of the proposed algorithm.

72_122 Productivity change in two-stage production system for multi-periods with negative data

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Multi periods are not taken into account by conventional two-stage data envelopment analysis (DEA) models. The research idea is to focus on the internal operations for multi-periods of both public and private NBFIs which can help expose that the private sector NBFIs are inherently inefficient than public sector NBFIs in India. In this paper, we consider two stages of NBFIs: premium acquisition (or deposit or first) and profit operations. premium acquisition stage is connected in series to the profit stage. This study examines productivity change over multi periods in a two-stage DEA during a period when the data are negative. This study examines the multi-period efficiency of Indian non bank financial institutions' (NBFI), two-stage operations with negative data and takes into account 4 years panel data (2018-2022). The objective of this study is to fill a gap in the literature in the field of NBFI in multi-period in two stage DEA with negative data, which determines the overall system efficiency as well as first stage (deposit) and second stage (profit) efficiencies and both stages are connected in series. To assess the impact of exogenous factors, we use the regression method in the second phase. Age and firm type are not significant, according to the regression results, but size and return on assets (ROA) are. Finally, we do a comparison between the public and private NBFIs. According to our findings, the public NBFIs performed better than the private NBFIs.

73_123 Predicting and evaluating efficiency of Indian banks in optimistic and pessimistic environments using DEA-SVR approach

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DEA, introduced in 1978, is a non-parametric linear programming-based technique for measuring the performance of a set of homogeneous peer entities called Decision Making Units (DMUs) which utilize multiple inputs to produce multiple outputs. DEA determines the best efficiency score that can be assigned to each DMU. Based on these scores, DMUs are classified into DEA-efficient or inefficient units. To analyze the performance of unit between different periods, DEA window analysis approach was

introduced. Windows analysis is a time dependent version of DEA to assesses the performance of a DMU over time by treating it as a different entity in each time period. However, increase in economical activities like merging of DMUs, increase in the number of DMUs, augmentation of DMU's failure etc. makes DEA calculation very cumbersome and it takes lot of computational capacity and time to re-run the whole DEA model. This has become a major limitation of DEA technique and it lacks predictive capabilities.

These limitations can be effectively prevented by using integrated DEA and machine learning approach like, Support vector machine for regression (SVR). To validate this approach, the present study evaluated and predicted the efficiency of Indian banks in optimistic and pessimistic environments with interval data in the presence of undesirable outputs. To analyze the performance of Indian banks window analysis in DEA-SVR approach for period 2015-2019 has been analyzed for public sector banks and private sector banks. To illustrate the impact of this DEA-SVR approach, the predicted efficiency scores of tested data has also been compared with the original DEA efficiency scores and least minimum square error proved robustness of the technique.

74_125 Understanding the determinants of reviewer credibility: an interpretive structural modeling and artificial neural network approach

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With the digitization of the tourism and hospitality sector, all hotel and travel bookings can be done online. Since the quality of experience is highly valued, feedback given by the customers is considered to be of great importance. This feedback in the form of electronic word of mouth (eWOM) can also serve as a deciding factor for potential customers. For this purpose, it is very crucial to have trust in the reviewer. Unlike the actual encounter, where trust is developed with the tone, body language, and facial expressions of the person, users have to rely on the reviewer's profile in the online scenario. Therefore, this study aims to understand the parameters that impact reviewer credibility. Parameters for the same are identified through literature review and expert opinions which are then converted into a hierarchical model using Interpretive Structural Modelling (ISM) technique to analyze the relationship among them. Further understanding of the interrelationships among the reviewer characteristics is attained using MICMAC analysis. To investigate the efficiency of the proposed approach, an artificial neural network (ANN) is used by the authors. This paper

provides some insightful findings for customers as well as hoteliers. It also holds the potential to make a significant contribution to this research area from both theoretical and practical perspectives.

75_126 Deterministic Optimal Mechanisms in Two-item Setting for Constant Power Rate Distributions

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76_127 Relation between a Bilevel Multiobjective Programming Problem and Wolfe Dual

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In this study, we have proposed a Wolfe-type dual for a multiobjective bilevel programming problem. Under generalized convexity assumptions on the functions involved, the relationship between the two prob-lems is studied via weak and strong duality theorems. The application of the discovered results is demonstrated through a few examples.

77_128 Stochastic modeling of energy optimization in hybrid base station in 5G Networks

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A hybrid energy system is a mixer of renewable and non-renewable sources of energy. Renewable sources of energy can fill up itself at the rate as it is used, while a non-renewable source of energy has a restricted supply. Renewable sources of energy include solar, wind, hydro power, thermal power plant, biomass etc. While non-renewable sources of energy include natural gas, coal, nuclear energy and diesel generator. To reduce the energy consumption and save the power in hybrid base station with non-renewable source, we have optimized the use of alternating current (AC) since it is mostly used everywhere by considering direct current (DC) along with AC power. We have developed a semi-Markov model to optimize the energy in hybrid base station. Further, the numerical results show how much energy in non-renewable sources can be saved by using the AC-DC approach in 5G networks.

78_129 Optimal channel selection considering price competition and information sharing under demand uncertainty

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Abstract: The rapid development of Internet technology has led to an increasingly significant role for e-commerce platforms in economic growth. There is a difference between the two modes in the E-commerce online channel. In terms of resale mode, the platform merchant wholesales from the manufacturer. Then, E-tailer1 resells the products to the consumers and then decides the products' online price in this mode. In the agency model, the manufacturer sells the product directly through the E-commerce online platform, where the manufacturer can set the price, and the platform E-tailer2 takes a percentage of sales revenue from the manufacturer. However, when the epidemic recedes, offline physical stores, which integrate experience, quality service, and social attributes, are still irreplaceable retail channels for the manufacturer.

In addition, the market is subject to demand uncertainty in both online and offline channels. Meanwhile, traditional retailers and the platform E-tailers can detect market fluctuations earlier. Although the manufacturer in the agency model has direct access to the market and owns the ability to adjust prices directly in the agency model when compared to the traditional retailers and the platform E-tailers of resale mode, the manufacturer's lower level of experience with sales makes it less sensitive to demand information in the marketplace. Therefore, we consider the traditional retailers and E-tailer1 to share the demand information with the manufacturer.

To explore how the green supply chain operates on different marketing channels with demand uncertainty, we develop a model to analyze the manufacturer's channel selection decision among the traditional offline channel, E-commerce online channel (resell mode, agency mode) and further consider the traditional retailers and E-tailer whether or not to share the demand information with the manufacturer. The results are as follows: Firstly, whether it is a traditional offline or an E-commerce

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online channel, information sharing does not affect the average wholesale and retail price. However, when the e-commerce retailer shares the private information data, the manufacturer adjusts the decision variables to reflect the changes in the demand signal, and E-tailer 1 will further change the retail price accordingly. Then, the accuracy of demand information is conducive to improving the information value, whether it is a traditional offline or E-commerce online channel. Still, the proportion of the platform rate will inhibit the positive demand signals effect.

Meanwhile, it is common that information sharing by retailers will cause double marginal effects, but price competition behavior will mitigate the effects. However, consumers' green awareness would exacerbate this phenomenon. In addition, when the platform proportion fee rate is low, the manufacturer prefers to operate on the e-commerce online channel. On the contrary, it is interesting that the profit of traditional retailers is greater than that of e-commerce in the case of lower platform fees. This is because the manufacturer will mainly rely on the agency channel, the low platform proportion fee rate leads to a low profit for E-tailer 2, and the price competition between the agency model and the resale model forces E-tailer1 not to set the retail price arbitrarily.

In terms of managerial implications and insights, sharing the demand information between the competing retailers and the manufacturer is always beneficial to the manufacturer. However, the increase in the platform proportion fee rate lowers the manufacturer's information value of the e-commerce channel than that of the traditional channel strategy. In addition, no matter how the platform fee rate changes, the retailers in traditional offline channels have greater information value without sharing information. Therefore, the manufacturer should motivate the retailers so that they can deliver the private demand signal to them. As the platform rate increases, the value of the information obtained by E-retailer 2 increases. Therefore, although the higher platform fee rate will increase the information value of E-retailer 2, it will force the manufacturer to give up this mode of operation. Moreover, E-tailer 2 of the agency mode should set the platform rate within a reasonable range. E-tailer 2's interests will be damaged if the rate is set lower. On the other hand, if the platform proportion fee rate is high, the manufacturer will not continue to choose this model to sell.

Finally, this study also clarifies the role of price competition and consumers' green awareness in an uncertain market and provides insights into the business of real life.

79_130 AN INTEGRATED MATHEMATICAL MODEL FOR 3PRLP SELECTION UNDER SUSTAINABILITY AND RISK CRITERIA

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Reverse Logistics (RL) has become a fundamental part of the Supply Chain (SC) for a sustainably viable business. Electronic Equipment Manufacturing (EEM) firms are highly determined to carry out Reverse Logistics (RL) activities for effective recovery of returned products and sustainable and economically efficient business. However, due to lack of expertise and resources in carrying out RL activities, Indian EEM prefer practising RL via outsourcing or under collaboration with qualified and experienced Third-Party Reverse Logistics Providers (3PRLPs). Small and Medium-sized Enterprises (SMEs) however face risks like third-party opportunism, lack of trust and expertise, poor communication and information flow and hence need to assess the impact of these risks prior to selection of 3PRLP for collaboration. It is very crucial to foresee the risk handling capabilities of 3PRLP before getting involved in sustainable collaboration with them as with increased benefits, RL brings risks to EEM SMEs. The proposed bi-objective mathematical model assists in achieving a trade-off between the profits earned by the EEM SMEs and choosing 3PRLP with high sustainable performance score while optimizing the RL network. The purpose of the model includes 3PRLP selection or collaboration with them based on sustainable and risk standards, determining the number of facilities required to open for RL activities and the number of returns to be processed at each node of the network.

In the extant literature, a number of researchers have identified the risks associated with implementation of RL in different industries. But none have discussed the risks faced by the Indian EEM SMEs associated with collaboration of EEM SMEs and 3PRLP. Moreover, none has focused upon evaluating the risk criteria in order to select sustainable 3PRLP for collaboration. Therefore, this paper tries to fill these research gaps by:

1. Identifying the risks faced by the Indian EEM SMEs associated with collaboration with 3PRLPs.
2. Ranking the risk criteria and selecting the optimal 3PRLP with the aid of a mathematical model.

Further, the mathematical model developed in this study is validated for the case of an Indian EEM SME dealing with returned electronic products. The EEM case company is an Indian SME which manufactures phone chargers, neck-bands, data cables and portable chargers. The case company practices RL by outsourcing some of the RL activities but it is now planning to collaborate with 3PRLPs for multiple reasons. However, looking at the risks of collaborating with 3PRLP, EEM SME wants to select the best 3PRLP while looking at all the risks and sustainability criteria fearing failure of RL.

The findings of the study could provide the Indian EEM SMEs with the ability to identify, manage and select the optimal 3PRLP for collaboration considering the sustainability criteria and risk simultaneously. The findings of the study aid in successful implementation of RL under collaboration with 3PRLP. It also exemplifies the potential in growth due to collaborative partnership between EEM SME and 3PRLP and elucidates its perquisites for the Indian electronic industry.

80_131 A Multi Objective Optimization Model for Facility Selection for Building an Agile and Responsive Circular Supply Chain

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In the last few years, due to emerging concerns like scarcity of the non-renewable resources, strict environmental regulations and increasing consumer preferences for environmentally-friendly products, the firms are starting to move from linear economy to circular economy (CE). CE aims to minimize pollutant emissions while maintaining high utility and value of products. The outbreak of COVID-19 pandemic has fuelled this transformation towards CE. The pandemic brought the world's attention towards resource scarcity and increasing environmental concerns due to which firms are focusing on redesigning their supply chains (SCs) in a circular fashion. For building an effective circular supply chain (CSC), SCs need to be flexible and responsive. The problem addressed in the current research is that of an electronics manufacturing firm who wants to set up their own collection and inspection centres (CICs) at their retail stores. For this purpose, we are proposing a multi-objective mathematical model for helping the firm in redesigning their Closed Loop Supply Chain (CLSC) network to build a CSC taking into account its agility, responsiveness and sustainability. CICs are an important part of CLSC where collection and inspection of the returned products are carried out. The firm wants to set up its CICs at the retail stores itself and are focusing on determining the expansion capacity of the selected retail stores to function as CICs. The selection of retail stores as CICs has been made on the basis of agility, responsiveness and sustainability criteria. Thus, the research objectives of this study are

1. Redesigning a CLSC network into a CSC network such that it is agile, responsive and sustainable.
2. Selection of the retail stores to act as CICs.
3. Determining the expansion capacity of the selected retail stores to function as CICs.

To achieve the above-mentioned research objectives, the retail stores are first divided into various zones and from each zone some of the retail stores are selected to function as CICs. For this purpose, a multi objective mathematical model representing a closed loop network has been formulated in this study. Minimisation of cost, maximisation of demand satisfaction and maximisation of the utility scores of the retail stores are the three objective functions considered in this study. Ɛ-constraint method has been used to solve the multi objective problem. The findings of the study will help the firm in taking the first step towards building a CSC keeping in mind the agility and responsiveness of the network.

81_132 Multi-Objective Approach for Smart Sustainable Supplier Selection and Order Allocation Model within Context of Circular Economy Implementation in Supply Chain Network

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Changes in government policies, escalating societal challenges, deteriorating workforce availability, changes in customer preferences, and deteriorating climatic conditions are forcing enterprises to incorporate Circular Economy (CE) and Industry 4.0 (I4.0) concepts for bringing sustainability into their supply chains. However, to accomplish the sustainable goals set by the enterprises, coordinated actions from all the supply chain actors are essential. In this context, suppliers are seen as the key players in any enterprise with whom closer integration and robust association are needed. It can aid the enterprise in meeting the technological, societal, economic, and environmental expectations of its clients/customers. Therefore, in the present study, a strong emphasis has been put on selecting a best-performing smart sustainable supplier on the basis of relevant I4.0 and CE-related criteria along with the traditional sustainability criteria. Further, an order allocation model is formulated to assign optimal orders to the suppliers based on their performance. The study particularly focuses on the Indian MSMEs sector involved in manufacturing electric bikes, where the owners often choose suppliers without considering CE, I4.0 and sustainability factors. With this pretext, we aim to fulfil the following research objectives:

1. To determine the best-performing smart sustainable suppliers based on CE, I4.0, and sustainability factors.
2. To formulate the optimization model for allocating optimal order quantity to the suppliers on the basis of their performance.

Methodology

To achieve the objectives mentioned above, an integrated model is developed to assist in creating a network that is cost-effective by identifying the top-performer supplier and effectively allocating order quantities. Firstly, a multi-criteria decision-making method called Best Worst Method (BWM) is utilized to evaluate the supplier scores based on CE, I4.0, and sustainability factors. Further, a multi objectives model is developed to minimize transportation, ordering, purchasing, and inventory costs along with the amount of carbon emission by inbound and outbound logistics. A case study of the electric bike manufacturing industry in the context of Indian MSMEs is considered to validate the model.

Results and Implications

The study's primary goal is to provide a practical integrated framework for the assessment and selection of the best-performer supplier as well as an order allocation model for the electric bike manufacturing industry in the context of Indian MSMEs. The optimization model is developed for optimal order allocation and conserving the constraints to fulfil the overall objectives. The finding of this study shows that carrying out ecological, societal, technological, and economic operations efficiently and efficiently helps enterprises lower the overall cost of the supply chain network. Moreover, the results also indicate that considering carbon emissions in an enterprise's business operations leads to an environmentally friendly working environment and aids in developing a solid reputation in the marketplace.