1st International Conference

on

Mathematical Optimization Theory and Applications

14–16 March 2026

Program and Abstract Booklet

Department of Mathematical Sciences

IIT (BHU) Varanasi, UP 221005, INDIA

Contents

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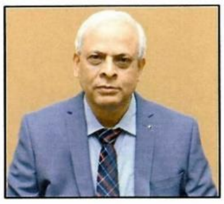
INDIAN INSTITUTE OF TECHNOLOGY
BANARAS HINDU UNIVERSITY

आचार्य अमित पात्रा
निदेशक
Prof. Amit Patra
Director



Message

It gives me great pleasure to know that the 1st International Conference on Mathematical Optimization Theory and Applications (ICMOTA 2026) is being organized at the Department of Mathematical Sciences, Indian Institute of Technology (BHU),Varanasi from March 14-16, 2026. Such conferences provide an important platform for researchers, academicians, and practitioners from across the globe to come together, exchange ideas, and discuss recent developments in mathematical optimization and statistical analysis and their diverse applications.

At IIT (BHU),Varanasi, we remain deeply committed to our vision of becoming a leading center for modern interdisciplinary technological advancement. In the spirit of the vision of Mahamana Pandit Madan Mohan Malaviya, we continue to emphasize the vital role of science, engineering, and technology in building a strong and self-reliant nation. Mathematical optimization and its applications are related to many emerging areas such as artificial intelligence, data science, machine learning, engineering design, and decision sciences. A conference like ICMOTA 2026 will undoubtedly foster meaningful discussions, encourage innovative research, and promote collaborations among scholars working in these domains.

Our institute firmly believes in promoting value-based excellence in education and research while nurturing a culture of integrity, innovation, and social responsibility. By encouraging interdisciplinary research and strengthening collaborations with industry and international academic communities, we aim to create knowledge that addresses real-world challenges and contributes to societal progress.

I congratulate the organizing committee for their efforts in hosting this international conference and bringing together experts and young researchers on a common platform. I am confident that ICMOTA 2026 will be intellectually enriching and will lead to fruitful interactions and long-lasting collaborations. I extend my best wishes for the grand success of the conference.

Patra

(Amit Patra)
Date: 09th March 2026

संस्कार ही शिक्षा **Education is Character**

आज़ादी का अमृत महोत्सव

भारतीय प्रौद्योगिकी संस्थान (का.हि.वि.वि), वाराणसी-221005 (भारत)
Indian Institute of Technology (BHU), Varanasi-221005 (INDIA)
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स्वच्छ भारत
एक कदम स्वच्छता की ओर

Program at a Glance

Venue for the entire program is the Department of Mathematical Sciences, IIT (BHU), Varanasi – 221005

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Patron

Prof. Amit Patra
Director, Indian Institute of Technology (BHU) Varanasi

Organizing Chairs

Dr. Debdas Ghosh
Department of Mathematical Sciences, IIT (BHU) Varanasi

Dr. Amit Kumar
Department of Mathematical Sciences, IIT (BHU) Varanasi

Convener
Prof. Subir Das
Department of Mathematical Sciences, IIT (BHU) Varanasi

Secretary

Dr. Anuradha Banerjee
Department of Mathematical Sciences, IIT (BHU) Varanasi

Treasurers
Dr. Kousik Dhara
Department of Mathematical Sciences, IIT (BHU) Varanasi

Dr. Satyendra Kumar Mishra
Department of Mathematical Sciences, IIT (BHU) Varanasi

Program Committee

Dr. Debdas Ghosh, IIT (BHU) Varanasi
Prof. Anurag Jayswal, IIT (ISM) Dhanbad
Dr. Amit Kumar, IIT (BHU) Varanasi
Prof. S. K. Neogy, ISI Delhi
Prof. Zai-Yun Peng, Yunnan Normal University, China
Prof. V. Vetrivel, IIT Madras

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Prof. Minh Dao, RMIT University, Australia
Prof. Q. H. Ansari, King Fahd University of Petroleum and Minerals, Saudi Arabia
Prof. Zai-Yun Peng, Yunnan Normal University, China
Prof. Zhiang Zhou, Chongqing University of Technology, China
Prof. Xian-Jun Long, Chongqing Technology and Business University, China

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Prof. Debjani Chakraborty, IIT Kharagpur
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Prof. V. Vetrivel, IIT Madras
Prof. Anurag Jayswal, IIT (ISM), Dhanbad
Prof. S. P. Yadav, IIT Roorkee

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Dr. Anoop Singh, IIT (BHU) Varanasi
Dr. Amit Kumar, IIT (BHU) Varanasi

Dr. Rakesh Arora, IIT (BHU) Varanasi
Dr. Manish Kumar Khandelwal, IIT (BHU) Varanasi
Dr. Satyendra Kumar Mishra, IIT (BHU) Varanasi
Dr. Kousik Dhara, IIT (BHU) Varanasi
Dr. Bivas Khan, IIT (BHU) Varanasi
Dr. Mustapha Bouallala, Cadi Ayyad University, Morocco
Mr. Nand Kishor, IIT (BHU) Varanasi
Mr. Ravi Raushan, IIT (BHU) Varanasi
Mr. Krishna Gupta, IIT (BHU) Varanasi
Mr. Jaydip Das, IIT (BHU) Varanasi
Ms. Tapasi Karmakar, IIT (BHU) Varanasi
Ms. Katyanai Priya, IIT (BHU) Varanasi
Mr. Poleen Kumar, IIT (BHU) Varanasi
Ms. Shavita Chaturvedi, IIT (BHU) Varanasi
Mr. Ashutosh Kasaudhan, IIT (BHU) Varanasi
Ms. Jeenee, IIT (BHU) Varanasi
Ms. Anureet Kaur, IIT (BHU) Varanasi
Mr. Alauddin Mondal, IIT (BHU) Varanasi

List of Speakers

Keynote Talk Speakers

Debjani Chakraborty, Indian Institute of Technology Kharagpur, India
Neeraj Misra, Indian Institute of Technology Kanpur, India
S. K. Neogy, Indian Statistical Institute, Delhi, India
Christiane Tammer, Martin-Luther-University Halle-Wittenberg, Germany
Tamás Terlaky, Lehigh University, USA

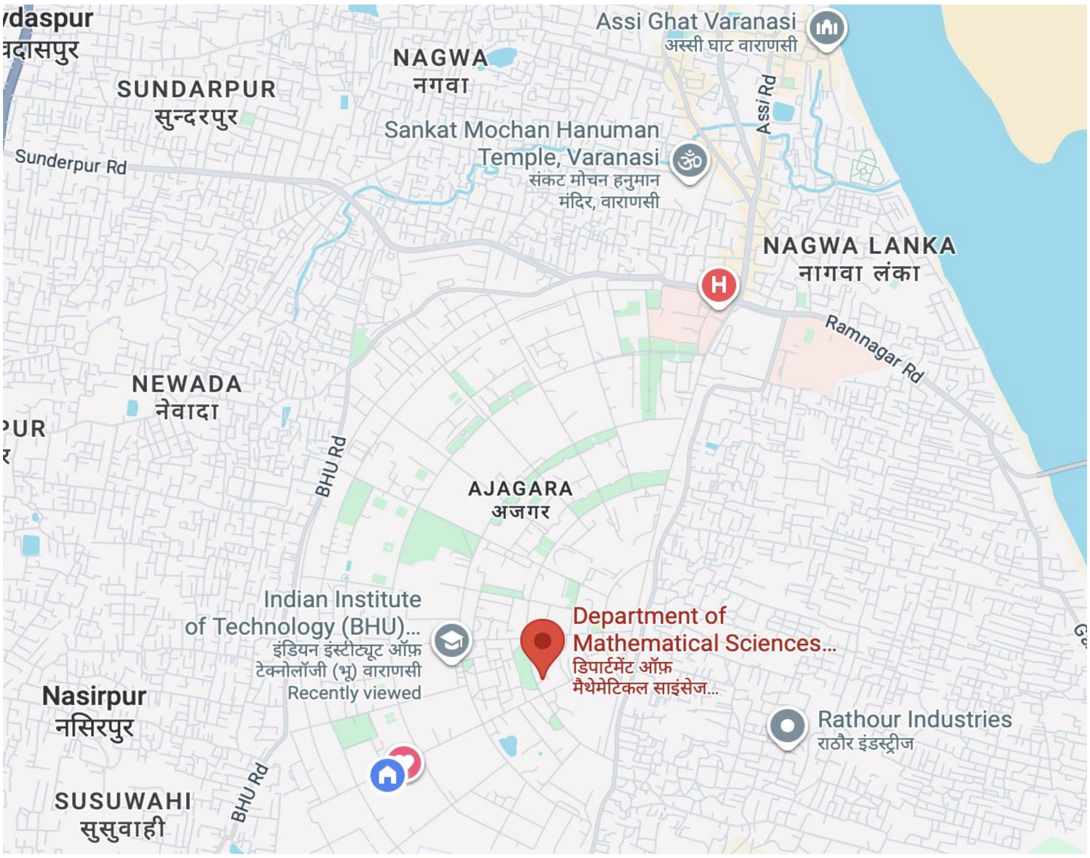
Plenary Talk Speakers

S. Dharmaraja, Indian Institute of Technology Delhi, India
Joydeep Dutta, Indian Institute of Technology Kanpur, India
Adrijit Goswami, Indian Institute of Technology Kharagpur, India
Anurag Jayswal, Indian Institute of Technology (ISM) Dhanbad, India
Debasis Kundu, Indian Institute of Technology Kanpur, India
Vinay Pandey, Indian Space Research Organization, Bengaluru, India
Bhupendra Singh, Scientist-F, CAIR, DRDO Bangalore
Radu Strugariu, Gheorghe Asachi Technical University of Lasi, Romania
Vellaisamy P., University of California, USA

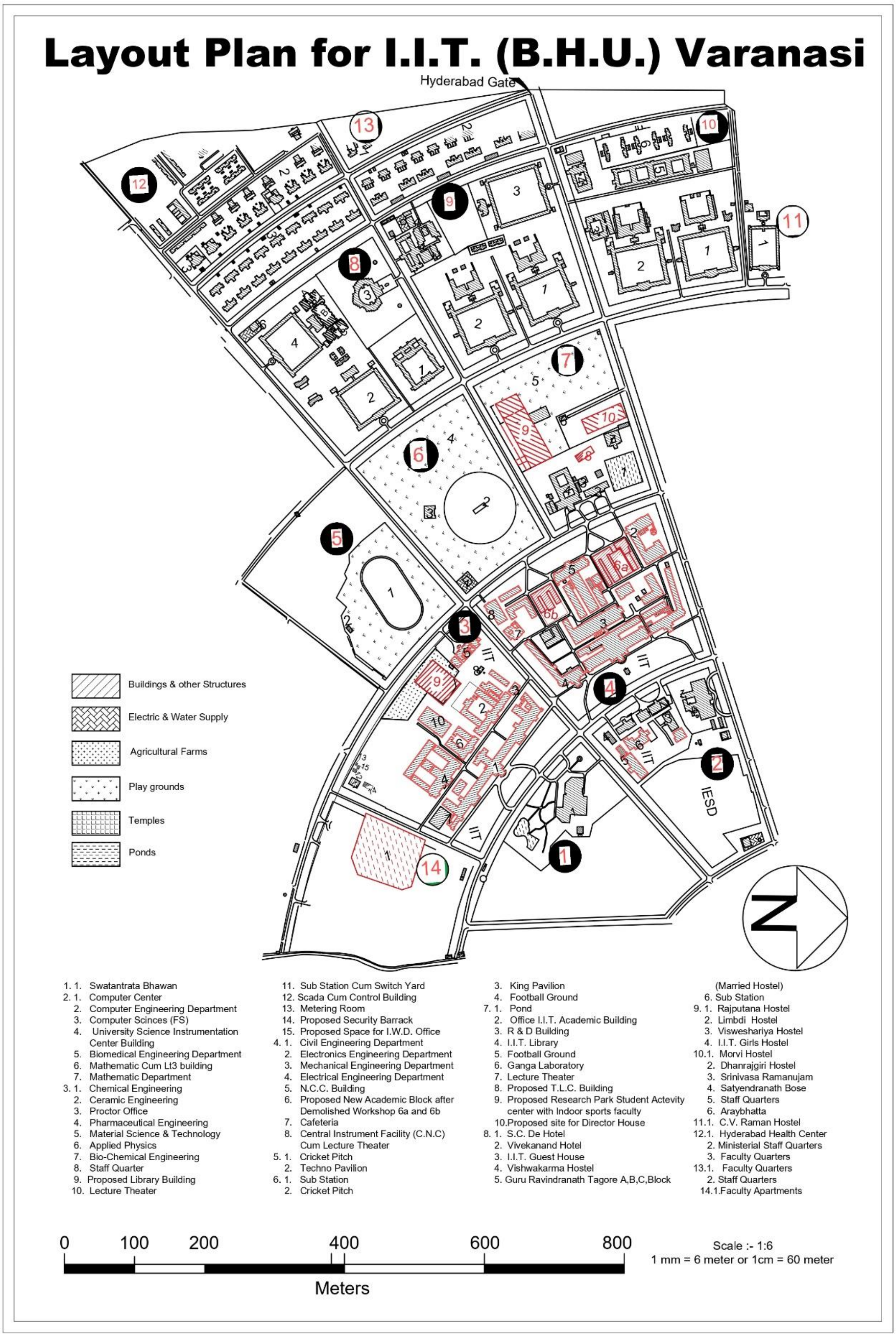
Neelesh S. Upadhye, Indian Institute of Technology Madras, India
S. P. Yadav, Indian Institute of Technology Roorkee, India

Invited Talk Speakers
Mohd. Arshad, Indian Institute of Technology Indore, India
Kalyan Barman, National Institute of Technology Warangal, India
Watcharporn Cholamjiak, University of Phayao, Thailand
Prasit Cholamjiak, University of Phayao, Thailand
Raju Chowdhury, ISI Kolkata, India
Minh Dao, RMIT University, Australia
Ishapathik Das, Indian Institute of Technology Tirupati, India
Pankaj Gautam, Indian Institute of Technology Roorkee, India
Shiv Kumar Gupta, Institute of Technology Roorkee, India
Nil Kamal Hazra, Indian Institute of Technology Jodhpur, India
Akhlad Iqbal, Aligarh Muslim University, India
Monirul Islam, Aligarh Muslim University, India
Jauny, Indian Institute of Technology Bhilai, India
Suchandan Kayal, National Institute of Technology Rourkela, India
Krishan Kumar, Indian Institute of Technology Kanpur, India
Nitin Kumar, Indian Institute of Technology Jammu, India
Vivek Laha, Banaras Hindu University, India
Naoki Marumo, University of Tokyo, Japan
Prashanta Majee, Motilal Nehru National Institute of Technology, Allahabad, India
Ashok Kumar Pathak, Central University of Punjab, India
Laxman Saha, Balurghat College, India
Kuntal Som, Indian Institute of Technology Jodhpur, India

Address of the Venue: Department of Mathematical Sciences, IIT (BHU) Varanasi, Uttar Pradesh, 221005, INDIA



Map of the Indian Institute of Technology (BHU) Varanasi



Weather Forecast (March 14-16, 2026)

Date	Weather	Temperature
March 14, 2026 (Saturday)	Mostly Sunny	16/33°C
March 16, 2026 (Sunday)	Plenty of Sunshine	17/33°C
March 17, 2026 (Monday)	Mostly Sunny	17/34°C

Conference Schedule			
March 14, 2026, Saturday			
Time	**Speaker**	**Location**	**Chair**
08:00—09:00	Breakfast Department of Mathematical Sciences, IIT (BHU)		
09:00—09:30	Registration		
09:30—10:30	**Inaugural Session: LT 2.11**		
10:30—10:40	**Group Photo**		
10:40—11:00	**High Tea Break**		
	Keynote Talk		
11:00—11:50	Prof. Neeraj Misra	LT-2.12	Prof. Debasis Kundu
11:50—12:40	Prof. Debjani Chakraborty	LT-2.12	Prof. Santawana Mukhopadhyay
	Plenary Talk		
12:40—13:20	Prof. N. S. Upadhye	LT-2.12	Prof. Debjani Chakraborty
13:20—15:00	**Lunch Break**		
15:00—15:40	Prof. Adrijit Goswami	LT-2.12	Prof. Neeraj Misra
15:40—16:20	Prof. Debasis Kundu	LT-2.12	Prof. N. S. Upadhye
16:20—17:00	Prof. Joydeep Dutta	LT-2.12	Prof. Adrijit Goswami
17:00—17:30	**Tea Break**		
	Invited Talk		
17:30—18:00	Dr. Mohd. Arshad	Ramanujan Hall	Dr. Amit Kumar
	Dr. Suchandan Kayal	Aryabhata Hall	Dr. Debdas Ghosh
	Dr. Kuntal Som	LT-2.11	Dr. Suchandan Kayal
	Dr. Jauny	LT-2.12	Dr. S. K. Mishra
	Dr. Vivek Laha	LT-2.21	Dr. A. K. Jha
	Dr. Vinay Pandey	LT-2.22	Dr. Anoop Singh
	Dr. Raju Chowdhury	LT-2.31	Dr. M. K. Khandelwal
18:00—18:30	Dr. Kalyan Barman	Ramanujan Hall	Dr. Amit Kumar
	Dr. Feeroz Babu	Aryabhata Hall	Dr. Debdas Ghosh
	Dr. Nitin Kumar	LT-2.11	Dr. Suchandan Kayal
	Dr. Ashok Kumar Pathak	LT-2.12	Dr. S. K. Mishra
	Dr. Avinash Dixit	LT-2.22	Dr. Anoop Singh
	Dr. Ashutosh Upadhayay	LT-2.31	Dr. M. K. Khandelwal
	Dr. Laxman Saha	LT-2.21	Dr. A. K. Jha
	Technical Session-I		
18:30—18:40	Haridas Mondal	Ramanujan Hall	Dr. Vishvesh Kumar
	Sumit Maheshwari	Aryabhata Hall	Dr. Sheela Verma

18:30—18:40	Naveen Kumar	LT 2.11	Dr. Kousik Dhara
	Athira V	LT 2.12	Dr. S. K. Mishra
	Sharmistha Acharyya	LT 2.21	Dr. Bivas Khan
	Shivam	LT 2.22	Dr. Rakesh Arora
	Anita Barman	LT 2.31	Dr. Amit Kumar
18:40—18:50	Nipa Jun-on	Ramanujan Hall	Dr. Vishvesh Kumar
	Saroj Kumar Pani	Aryabhata Hall	Dr. Sheela Verma
	Anurag Sharma	LT 2.11	Dr. Kousik Dhara
	Shubhayu Brahmachari	LT 2.12	Dr. S. K. Mishra
	Anureet Kaur	LT 2.21	Dr. Bivas Khan
	Arindam Maity	LT 2.22	Dr. Rakesh Arora
	Gannamaneni Sai Charan	LT 2.31	Dr. Amit Kumar
18:50—19:00	Shweta Upadhyaya	Ramanujan Hall	Dr. Vishvesh Kumar
	Aswani Thomas	Aryabhata Hall	Dr. Sheela Verma
	Atrii Roy	LT 2.11	Dr. Kousik Dhara
	Harvinth K	LT 2.12	Dr. S. K. Mishra
	Nityansh Pant	LT 2.21	Dr. Bivas Khan
	Krishna Gupta	LT 2.22	Dr. Rakesh Arora
	Anu Karwashra	LT 2.31	Dr. Amit Kumar
19:00—19:10	Abhijit Datta Banik	Ramanujan Hall	Dr. Vishvesh Kumar
	Watcharapon Yajai	Aryabhata Hall	Dr. Sheela Verma
	Tina Sharma	LT 2.11	Dr. Kousik Dhara
	Sonam Sharma	LT 2.12	Dr. S. K. Mishra
	Meenakshi	LT 2.21	Dr. Bivas Khan
	Ashwani Dubey	LT 2.22	Dr. Rakesh Arora
	Suman Ghosh	LT 2.31	Dr. Amit Kumar
19:10—19:20	Ruchira Goel	Ramanujan Hall	Dr. Vishvesh Kumar
	Deepak Chandra Sau	Aryabhata Hall	Dr. Sheela Verma
	Mayank Jashnani	LT 2.11	Dr. Kousik Dhara
	Katyayni Priya	LT 2.12	Dr. S. K. Mishra
	Kartikyan	LT 2.21	Dr. Bivas Khan
	Ayushi Verma	LT 2.22	Dr. Rakesh Arora
	Ganesh Kumar Sahoo	LT 2.31	Dr. Amit Kumar
19:20—19:30	Bhawna Kohli	Ramanujan Hall	Dr. Vishvesh Kumar
	Milan Barik	Aryabhata Hall	Dr. Sheela Verma
	Gaurav Uniyal	LT 2.11	Dr. Kousik Dhara
	Bishal Biswas	LT 2.12	Dr. S. K. Mishra
	Anjali Sharma	LT 2.21	Dr. Bivas Khan
	Madhav Singh	LT 2.22	Dr. Rakesh Arora
	Shiwani Singh	LT 2.31	Dr. Amit Kumar
19:30—19:40	Kaushik Gupta	Ramanujan Hall	Dr. Vishvesh Kumar

19:30—19:40	Urmik Bhavsar	Aryabhata Hall	Dr. Sheela Verma
	Jaydip Das	LT 2.11	Dr. Kousik Dhara
	Manimaran S	LT 2.12	Dr. S. K. Mishra

Program at a Glance

Venue for the entire program is the Department of Mathematical Sciences, IIT (BHU), Varanasi – 221005

Date	**Program**	**Venue**
March 14, 2026	Registration	LT 2.12
	Opening Ceremony	
	Group Photo	
	Keynote Talk	
	Plenary Talk	
	Invited Talk	Ramanujan Hall Aryabhata Hall LT 2.11 LT 2.12 LT 2.21 LT 2.22 LT 2.31
	Technical Sessions	Ramanujan Hall Aryabhata Hall LT 2.11 LT 2.12 LT 2.21 LT 2.22 LT 2.31
March 15, 2026	Keynote Talk	LT 2.12
	Plenary Talk	
	Invited Talk	Ramanujan Hall Aryabhata Hall LT 2.11 LT 2.12 LT 2.21 LT 2.22 LT 2.31
	Technical Sessions	Ramanujan Hall Aryabhata Hall LT 2.11 LT 2.12 LT 2.21 LT 2.22 LT 2.31
	Special Session on AI and Software	LT 2.12
	Banquet Dinner	
	Best Paper Presentations	Ramanujan Hall
	Plenary Talk	
	Invited Talk	Ramanujan Hall Aryabhata Hall

March 16, 2026	Technical Sessions	Ramanujan Hall Aryabhata Hall Faculty Building
	Valedictory Function	Ramanujan Hall
	Local Tour	Sarnath and Other Places

Conference Schedule			
March 14, 2026, Saturday			
Time	**Speaker**	**Location**	**Chair**
08:00—09:00	Breakfast Department of Mathematical Sciences, IIT (BHU)		
09:00—09:30	Registration (Kit collection)		
09:30—10:30	**Inaugural Session: LT 2.12**		
10:30—10:40	**Group Photo**		
10:40—11:00	**High Tea Break**		
	Keynote Talk		
11:00—11:50	Prof. Neeraj Misra	LT-2.12	Prof. Debjani Chakraborty
11:50—12:40	Prof. Debjani Chakraborty	LT-2.12	Prof. Santawana Mukhopadhyay
	Plenary Talk		
12:40—13:20	Prof. Radu Strugariu	LT-2.12	Prof. Neeraj Misra
13:20—15:00	**Lunch Break**		
15:00—15:40	Prof. Adrijit Goswami	LT-2.12	Prof. N. S. Upadhye
15:40—16:20	Prof. N. S. Upadhye	LT-2.12	Prof. Adrijit Goswami
16:20—17:00	Prof. Joydeep Dutta	LT-2.12	Prof. N. S. Upadhye
17:00—17:30	**Tea Break**		
	Invited Talk		
17:30—18:00	Dr. Mohd. Arshad	Ramanujan Hall	Dr. Naoki Marumo
	Dr. Suchandan Kayal	Aryabhata Hall	Dr. Radu Strugariu
	Dr. Kuntal Som	LT-2.11	Dr. S. K. Mishra
	Dr. Pankaj Gautam	LT-2.12	Dr. Kalyan Barman
	Dr. Vivek Laha	LT-2.21	Dr. Saroj Kumar Pani
	Dr. Vinay Pandey	LT-2.22	Dr. Avinash Dixit
	Dr. Raju Chowdhury	LT-2.31	Dr. M. K. Khandelwal
18:00—18:30	Dr. Kalyan Barman	Ramanujan Hall	Dr. Mohd. Arshad
	Dr. Prasit Cholamjiak	Aryabhata Hall	Dr. Suchandan Kayal
	Dr. Nitin Kumar	LT-2.11	Dr. Kuntal Som
	Prof. Anurag Jayswal	LT-2.12	Dr. Pankaj Gautam
	Dr. Avinash Dixit	LT-2.22	Dr. Vinay Pandey

	Dr. Akhlad Iqbal	LT-2.21	Dr. M. K. Khandelwal
	Dr. Laxman Saha	LT-2.31	Dr. Vivek Laha
	Technical Session-I		
18:30—18:40	Mithu Rani Kuiti	Ramanujan Hall	Dr. Mohd. Arshad
	Sumit Maheshwari	Aryabhata Hall	Dr. Suchandan Kayal
	Naveen Kumar	LT 2.11	Dr. Kuntal Som
	Athira V	LT 2.12	Dr. Pankaj Gautam
	Anita Barman	LT 2.21	Dr. M. K. Khandelwal
	Shivam	LT 2.22	Dr. Vinay Pandey
	Sharmistha Acharyya	LT 2.31	Dr. Vivek Laha
18:40—18:50	Nipa Jun-on	Ramanujan Hall	Dr. Pankaj Gautam
	Saroj Kumar Pani	Aryabhata Hall	Dr. Suchandan Kayal
	Anurag Sharma	LT 2.11	Dr. Kuntal Som
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	Gannamaneni Sai Charan	LT 2.31	Dr. Raju Chowdhury
18:50—19:00	Shweta Upadhyaya	Ramanujan Hall	Dr. Avinash Dixit
	Aswani Thomas	Aryabhata Hall	Dr. Suchandan Kayal
	Atrii Roy	LT 2.11	Dr. Kuntal Som
	Harvinth K	LT 2.12	Dr. Pankaj Gautam
	Nityansh Pant	LT 2.21	Dr. Vivek Laha
	Krishna Gupta	LT 2.22	Dr. Vinay Pandey
	Anu Karwashra	LT 2.31	Dr. Raju Chowdhury
19:00—19:10	Abhijit Datta Banik	Ramanujan Hall	Dr. Saroj Kumar Pani
	Watcharapon Yajai	Aryabhata Hall	Dr. Avinash Dixit
	Tina Sharma	LT 2.11	Dr. Kuntal Som
	Sonam Sharma	LT 2.12	Dr. Pankaj Gautam
	Meenakshi	LT 2.21	Dr. Vivek Laha
	Ashwani Dubey	LT 2.22	Dr. Vinay Pandey
	Suman Ghosh	LT 2.31	Dr. Raju Chowdhury
19:10—19:20	Ruchira Goel	Ramanujan Hall	Dr. Akhlad Iqbal
	Deepak Chandra Sau	Aryabhata Hall	Dr. Avinash Dixit
	Mayank Jashnani	LT 2.11	Dr. Kuntal Som
	Katyayni Priya	LT 2.12	Dr. Pankaj Gautam
	Kartikyan	LT 2.21	Dr. Vivek Laha
	Ayushi Verma	LT 2.22	Dr. Vinay Pandey
	Ganesh Kumar Sahoo	LT 2.31	Dr. Raju Chowdhury
19:20—19:30	Haridas Mondal	Ramanujan Hall	Dr. Akhlad Iqbal
	Milan Barik	Aryabhata Hall	Dr. Avinash Dixit
	Gaurav Uniyal	LT 2.11	Dr. Kuntal Som
	Bishal Biswas	LT 2.12	Dr. Pankaj Gautam

	Anjali Sharma	LT 2.21	Dr. Vivek Laha
	Madhav Singh	LT 2.22	Dr. Vinay Pandey
	Shiwani Singh	LT 2.31	Dr. Raju Chowdhury
19:30—19:40	Kaushik Gupta	Ramanujan Hall	Dr. Akhlad Iqbal
	Urmik Bhavsar	Aryabhata Hall	Dr. Avinash Dixit
	Jaydip Das	LT 2.11	Dr. Kuntal Som
	Manimaran S	LT 2.12	Dr. Pankaj Gautam
	Anupam	LT 2.21	Dr. Vivek Laha
	Hima Saxena	LT 2.22	Dr. Vinay Pandey
	Himanshi Singh	LT 2.31	Dr. Raju Chowdhury
19:40—19:50	Tanmay Sahoo	Ramanujan Hall	Dr. Akhlad Iqbal
	Tapasi Karmakar	Aryabhata Hall	Dr. Avinash Dixit
	Vishal Goyal	LT 2.11	Dr. Kuntal Som
	P Vivek	LT 2.12	Dr. Pankaj Gautam
	Muskan Kumari, Vanshita Jindal	LT 2.21	Dr. Vivek Laha
	Hardeep Singh Saluja	LT 2.22	Dr. Vinay Pandey
	Priyanka Priyadarshini Behera	LT 2.31	Dr. Raju Chowdhury
19:50—20:00	Pradeep Rai	Ramanujan Hall	Dr. Akhlad Iqbal
	Sagar Sahoo, Sharath Y Kudachi, Rakshak M K, Vaibhav Pandey	Aryabhata Hall	Dr. Avinash Dixit
	Anshumaan Tanwar	LT 2.11	Dr. Kuntal Som
	Gayatri Beniya	LT 2.12	Dr. Pankaj Gautam
		LT 2.21	Dr. Vivek Laha
	Sudeeksha Tripathi	LT 2.22	Dr. Vinay Pandey
	Kuntal Roy	LT 2.31	Dr. Raju Chowdhury
20:00—22:00	**Dinner**		

Conference Schedule			
March 15, 2026, Sunday			
Time	**Speaker**	**Location**	**Chair**
08:00—09:00	Breakfast Department of Mathematical Sciences, IIT (BHU)		
	Keynote Talk		
09:00—09:50	Prof. Tamás Terlaky	LT-2.12	Dr. Debdas Ghosh
	Invited Talk		
09:50—10:20	Prof. Vellaisamy P.	Ramanujan Hall	Prof. Subir Das
	Prof. Watcharaporn Cholamjiak	Aryabhata Hall	Dr. Debdas Ghosh
	Prof. Samarjit Kar	LT-2.11	Dr. S. K. Neogy
	Dr. Prashanta Majee	LT-2.22	Dr. S. K. Mishra
	Dr. Nil Kamal Hazra	LT-2.31	Dr. Ishapathik Das
10:20—11:00	**Tea Break**		
	Keynote Talk		
11:00—11:50	Debashish Kundu	LT-2.12	Prof. S. Dharmaraja
11:50—12:40	Prof. S. K. Neogy	LT-2.12	Prof. Samarjit Kar
	Plenary Talk		
12:40—13:20	Prof. S. Dharmaraja	LT-2.12	Prof. S. P. Yadav
13:20—14:30	**Lunch Break**		
	Keynote Talk		
14:30—15:10	Prof. Christiane Tammer	Aryabhata Hall	Dr. Debdas Ghosh
	Plenary Talk		
15:10—15:50	Dr. Bhupendra Singh	LT-2.12	Prof. S. P. Yadav
15:50—16:30	Prof. S. P. Yadav	LT-2.12	Dr. Bhupendra Singh
16:30—17:00	**Tea Break**		
	Invited Talk		
17:00—17:30	Dr. Ashok Kumar Pathak	Ramanujan Hall	Dr. S. K. Mishra
	Dr. Ishapathik Das	Aryabhata Hall	Dr. Rakesh Arora
	Dr. Krishan Kumar	LT-2.11	Dr. A. K. Jha
	Prof. Shiv Kumar Gupta	LT-2.12	Prof. Samarjit Kar
	Dr. Monirul Islam	LT-2.21	Dr. Sheela Verma
	Technical Session-II		
17:15—17:30	Dr. Prasenjit Dutta	LT 2.22	Dr. Bivas Khan
17:30—17:40	Amir Suhail	Ramanujan Hall	Dr. S. K. Mishra
	Shalini	Aryabhata Hall	Dr. Rakesh Arora
	Shristi Singh	LT 2.11	Dr. A. K. Jha
	Naina Singh	LT 2.12	Prof. Samarjit Kar
	Khushvi Shah, Neelay Jain	LT 2.21	Dr. Sheela Verma

	Deeksha Singh	LT 2.31	Dr. Monirul Islam
	Dr. Swarup Paul	LT 2.22	Dr. Bivas Khan
17:40—17:50	Jeenee & Ravi Raushan	Ramanujan Hall	Dr. S. K. Mishra
	Barsha Shaw	Aryabhata Hall	Dr. Rakesh Arora
	Aman Raj Anand	LT 2.11	Dr. A. K. Jha
	Raina Raj	LT 2.12	Prof. Samarjit Kar
	Medepalli Renuka Vashisth & Hieya Chaturvedi	LT 2.21	Dr. Sheela Verma
	Ravi Kant	LT 2.22	Dr. Bivas Khan
17:50—18:00	Shivshankar Nila	Ramanujan Hall	Dr. S. K. Mishra
	Abhishek Srivastava	Aryabhata Hall	Dr. Rakesh Arora
	Bikram Adhikary	LT 2.11	Dr. A. K. Jha
	Bhawna Kohli	LT 2.12	Prof. Samarjit Kar
	Yatin Kumar	LT 2.21	Dr. Sheela Verma
	Alka Arya	LT 2.22	Dr. Bivas Khan
	Vishal Shukla	LT 2.31	Dr. Monirul Islam
	Special Session on AI and Software		
18:00—18:30	Dr. Sundar	Aryabahta Hall	Prof. Shyam Kamal
18:30—19:00	Prof. S. K. Singh	Aryabahta Hall	Dr. Sham Kamal
19:00—19:30		Aryabahta Hall	Dr. Shyam Kamal
19:30—21:00	**Cultural Program**		
21:00—22:30	**Banquet Dinner**		

Conference Schedule			
March 16, 2026, Monday			
Time	**Speaker**	**Location**	**Chair**
08:00—09:00	Breakfast Department of Mathematical Sciences, IIT (BHU)		
	Best Paper Presentation (Competition)		
09:00—09:15	Anjali Awasthi	Ramanujan Hall	Prof. Radu Strugariu Prof. S. K. Neogy
09:15—09:30	Nand Kishor	Ramanujan Hall	
09:30—09:45	Dr. Tapas Mondal	Ramanujan Hall	
09:45—10:00	Ajeet Kumar	Ramanujan Hall	
10:00—10:15	Ishu Jain	Ramanujan Hall	
10:15—10:30	Rohini Bhagwanrao Pote	Ramanujan Hall	
10:30—10:45	Sagnic Naskar	Ramanujan Hall	
10:45—11:00	Paragya Gupta	Ramanujan Hall	
11:00—11:15	**Tea Break**		
	Invited Talk		
11:15—11:45	Dr. Naoki Marumo	Ramanujan Hall	Prof. Radu Strugariu
	Dr. Minh Dao	Aryabhata Hall	Dr. Debdas Ghosh
	Prof. S. K. Gupta	Classroom, Faculty Building 1st Floor	Dr. Naoki Marumo
	Technical Session-III		
11:45—11:55	Anjali Rawat	Aryabhata Hall	Prof. S. P. Yadav
	Manohar Choudhary	Ramanujan Hall	Prof. Radu Strugariu
	C. S. Nagadarahas Kumar	Classroom, Faculty Building 1st Floor	Prof. S. K. Neogy
11:55—12:05	Sundaram Jha, Sakshi Gupta	Ramanujan Hall	Prof. Radu Strugariu
	Indu Ghosh	Aryabhata Hall	Prof. S. P. Yadav
	Abhishek Dixit	Classroom, Faculty Building 1st Floor	Prof. S. K. Neogy
	Girish Kumar Yadav	Classroom, Faculty Building 2nd Floor	Dr. Naoki Marumo
12:05—12:15	Ritik Gupta	Ramanujan Hall	Prof. Radu Strugariu
	Shaurya Singh	Aryabhata Hall	Prof. S. P. Yadav
	Tanishka Gupta	Classroom, Faculty Building 1st Floor	Prof. S. K. Neogy
	Rajdeep Singh Parihar	Classroom,	Dr. Naoki Marumo

		Faculty Building 2nd Floor	
12:15—12:25	Dr. Arindam Chakraborty	Ramanujan Hall	Prof. Radu Strugariu
	Shreya Pandey	Aryabhata Hall	Prof. S. P. Yadav
	Karan Verma	Classroom, Faculty Building 1st Floor	Prof. S. K. Neogy
	Simran Rawat	Classroom, Faculty Building 2nd Floor	Dr. Naoki Marumo
12:25—12:35	Kierat Kaur	Ramanujan Hall	Prof. Radu Strugariu
	Navita Pal	Aryabhata Hall	Prof. S. P. Yadav
	Astha Kumari, Dixita Barua	Classroom, Faculty Building 1st Floor	Prof. S. K. Neogy
	Keshav Kashyap & Abhisoumya Kapoor	Classroom, Faculty Building 2nd Floor	Dr. Naoki Marumo
12:35—12:45	Prasenjit Dutta	Ramanujan Hall	Prof. Radu Strugariu
	Vaishali Anand	Aryabhata Hall	Prof. S. P. Yadav
	Shivangi Singh	Classroom, Faculty Building 1st Floor	Prof. S. K. Neogy
	Priti Lata	Classroom, Faculty Building 2nd Floor	Dr. Naoki Marumo
12:45—12:55	Poleen Kumar	Ramanujan Hall	Prof. Radu Strugariu
	Mansi Sethi	Aryabhata Hall	Prof. S. P. Yadav
	Akash Gupta & Atharva Sanjay Hiremath	Classroom, Faculty Building 1st Floor	Prof. S. K. Neogy
	Darshana Yadav	Classroom, Faculty Building 2nd Floor	Dr. Naoki Marumo
12:55—14:00	**Lunch Break**		
14:00—14:30	**Valedictory Function: Ramanujan Hall**		
14:30—14:45	**Tea Break**		
15:00—19:30	**Local Tour**		
19:30—21:30	**Dinner**		

Keynote Talk

A trust region-based approach for Bayesian optimization

Debjani Chakraborty
Indian Institute of Technology Kharagpur, India

Abstract: Bayesian Optimisation is a popular framework for optimising black box functions, but it's often inefficient for high-dimensional problems because the search space grows exponentially, the objective function is heterogeneous, and the sampling budget is low. To overcome these issues, this work proposes a trust region-based Bayesian optimization technique. The proposed method is applied to the portfolio optimization problem to verify its applicability in real-world scenarios.

Dr. Debjani Chakraborty is a Professor in the Department of Mathematics at the Indian Institute of Technology (IIT) Kharagpur. She completed her Ph.D. (1995) from IIT Kharagpur. A distinguished academic and researcher, she has received numerous accolades, including the Young Scientist Award (1997) from the Indian Science Congress Association, the DST Young Scientist Scheme, and multiple Best Paper and Best Presentation Awards at national and international forums. She is a Fellow of the Operational Research Society of India (2023) and the West Bengal Academy of Science & Technology (2024), and a nominated member of the Indian National Academy of Sciences. With 175 publications and supervision of 15 completed and 9 ongoing Ph.D. scholars, along with 80 Master's projects, she has made significant contributions to research and mentorship in optimization, fuzzy systems, and decision sciences.

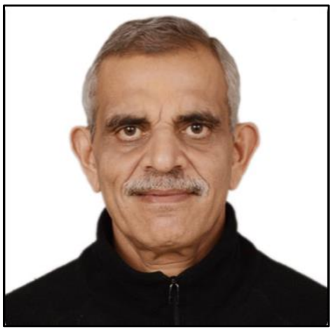
Her research spans optimization, fuzzy and stochastic modeling, multicriteria decision making, machine learning, and healthcare analytics. She has led and co-led numerous major research projects funded by DST, ICMR, SERB, MHRD, and other national agencies, including cutting-edge interdisciplinary initiatives in AI-driven healthcare diagnostics, glaucoma detection, cancer biomarker analysis, and predictive medical modeling. She has also undertaken important consultancy projects with industry and government organizations. Beyond research, Prof. Chakraborty has delivered extensive NPTEL and MOOC lecture series on Optimization and Mathematics for Machine Learning, and has held several key academic and administrative positions, including Associate Dean (Outreach) at IIT Kharagpur and membership in national committees such as AICTE-QIP and SERB Programme Advisory Committees. She also serves as Associate Editor of reputed international journals and is actively engaged in national and international academic advisory roles.

Keynote Talk

Adaptive Designs for Selection of Effective Treatments and Estimating Their Worth

Neeraj Misra (Joint work with Yogesh Kataria)
Indian Institute of Technology Kanpur, India

Abstract: In drug development clinical studies, multiple new treatments (drugs) for a specific disease are of interest for evaluation, selection and confirmation. In such studies, a problem of interest is selecting (identifying) effective treatments from a set of available treatments and estimating their worth. Traditional designs are not appropriate for such problems as they do not allow any modifications in trials in between (e.g., dropping unsafe drugs interim), resulting in patients being unexposed to unsafe drugs. Due to these drawbacks of traditional designs, adaptive designs have become quite popular during the last thirty-five years. In this talk we will discuss some adaptive designs for selection of effective treatments and estimation of their worth, with special reference to Drop-the-Loser Design (DLD).



Prof. Neeraj Misra is a Professor (HAG) in the Department of Mathematics and Statistics at the Indian Institute of Technology (IIT) Kanpur, a position he has held since August 2012. He earned his Ph.D. and M.Sc. in Statistics from IIT Kanpur. His long-standing career at IIT Kanpur includes serving as Head of the Department of Mathematics and Statistics (2008–2011) and Dean of Academic Affairs (2015–2018). Prof. Misra has also held several visiting and adjunct positions, most recently as a Professor at the University of California, Santa Barbara, and as an Adjunct Professor at SRM Institute of Science and Technology.

His research expertise lies in Reliability Theory, Stochastic Orders, and Ranking and Selection Problems. He has authored over 100 research papers in prestigious journals such as the Journal of Statistical Planning and Inference, IEEE Transactions on Information Theory, and European Journal of Operations Research. In recognition of his significant contributions, he was honored with the Lifetime Achievement Award (2023) by the Indian Association of Reliability and Statistics and the Gopal Das Bhandari Distinguished Teacher Award (2025) at IIT Kanpur. Prof. Misra is also currently preparing a book titled Probability and Distributions aimed at strengthening the conceptual foundations of Master's level students.

Beyond academia, Prof. Misra has made substantial contributions to national-level educational administration, serving on various committees for the National Testing Agency (NTA) regarding confidential operations and the normalization of JEE (Main) marks. He has successfully supervised 12 Ph.D. students who now hold faculty positions at prestigious institutions like IIT Delhi, IIT Kharagpur, IIT Indore and IIM

Lucknow. Professionally, he serves as an Associate Editor for several journals, including Communications in Statistics and the Journal of the Iranian Statistical Society, and acts as an ad-hoc referee for leading publications like Metrika and Operations Research Letters. Additionally, he has led consultancy projects evaluating skill in games for private companies like Winzo.

Keynote Talk

On a Class of Nonconvex Optimization Problems

S. K. Neogy
Indian Statistical Institute Delhi Centre, India

Abstract: Let $M = (X, d)$ be a finite metric space, where $X = \{x_1, x_2, \dots, x_n\}$. The distance matrix D of the metric space in the $n \times n$ matrix $D = [d_{i,j}]$, where $d_{i,j} = d(x_i, x_j)$. The metric space is completely described by its distance matrix. As a generalization of the diameter, the notion of "transfinite diameter" has been introduced in the literature. It turns out that the transfinite diameter of M is equal to the maximum of $x'Dx$ over $x \in \mathcal{P}_n$ where $\mathcal{P}_n = \{x \in R^n : x \geq 0, \sum_{i=1}^{n} x_i = 1\}$. The vector that attains the maximum has been called ∞-extender of M. More general versions of it have occurred in the literature in different contexts. These include some classical work on equilibrium points of symmetric bimatrix games and maximizing weighted average distance in graphs. We show that this class of problem can be reformulated as a strictly convex quadratic programming problem. This answers the open problem posed by Dankelmann about solving the above problem in polynomial time.

Prof. S. K. Neogy received his Ph.D. degree from Indian Statistical Institute. He was the former Head of the Indian Statistical Institute, Delhi Centre. His teaching interests include Mathematical optimization, Applied Statistics, Matrix Analysis, Special Matrices, and Static and Dynamic Games. Currently, he is in the Centre for Research and Data Analysis of the Indian Statistical Institute, Delhi Centre. Apart from a large number of theoretical contributions, he has made many real-life applications of Operations Research and applied Statistics. Prof. Neogy's Erdős number is 3.

His current research interests include Applied statistics, Optimization in Static & Dynamic environment, Stochastic Games, Non-cooperative games, Semi-Markov games, Complementarity Theory (which include Linear programming, Convex quadratic programming, Linear Fractional Programming etc), Generalized Convexity, Non-linear programming, Combinatorial Optimization and Matrix Analysis in Optimization theory.

Prof. Neogy has visited a number of countries like the USA, Japan, Australia, Turkey, Germany, Italy, France, Hungary, the Netherlands, Copenhagen, Switzerland, the UK, etc, for collaborative research, published widely in international journals, and coauthored/coedited a number of books/Research monographs. Prof. Neogy has attended and organized many International Conferences, and he is associated with numerous international journals in Operations Research and Game Theory.

Keynote Talk

Construction of Vector-Valued Weak Separation Functions with Applications to Conjugate Duality in Vector Optimization

Christiane Tammer (joint work with Siqi Wang and Chaoli Yao)
Martin-Luther-University Halle-Wittenberg, Germany

Abstract: We establish a unified framework for conjugate duality theory for constrained vector optimization problems using vector-valued nonlinear weak separation and topical functions (see [1]). The advantage of this new approach is that we compare objective function values of the primal and dual problem in the (extended) image space of the primal objective function. Furthermore, in the formulation of the duality statements, we avoid a scalarization. In our previous paper [2], collections of scalar weak separation functions were proposed for image space analysis, while this talk is concerned with vector-valued weak separation functions. Using vector-valued separation functions, the dual model is given for the vector optimization problem directly, unlike the previous work [3], where the primal problem was scalarized. We study a pair of a primal vector-valued problem and a dual set valued problem and derive weak as well as strong duality assertions for this pair.

References

[1] Rubinov, A.M. and I. Singer (2001), Topical and sub-topical functions, downward sets and abstract convexity, Optimization, vol.50, n. 5-6, pp.307-351.
[2] Yao, C.L. and C. Tammer (2023), Weak separation functions constructed by Gerstewitz and topical functions with applications in conjugate duality, J. Nonlinear Var. Anal., vol. 7, n. 5, pp. 859-896.
[3] Yao, C.L. and S.J. Li (2020), Conjugate duality for constrained vector optimization in abstract convex frame. Numer. Func. Anal. Optim., vol.40, pp. 1242-1267.

Prof. Christiane Tammer is currently in the Institute of Mathematics, Martin-Luther-University Halle-Wittenberg, Germany. She completed her doctorate at the Technical University of Merseburg in 1984 and her habilitation in 1991. She held visiting professorships at the University of Leipzig, the Royal Military College of Canada in Kingston, and the University of Kaiserslautern. From 1998 to 2021, she was a professor of variational methods at Martin Luther University of Halle-Wittenberg. From 2018 to 2021, she was the dean of research at the same university. Since 2021, she has been a professor emerita at the Martin Luther University of Halle-Wittenberg. Since 2018, she has been a member of the Scientific Committee of the Working Group on Generalized Convexity and the EUROPT Managing Board.

She is the editor-in-chief of the journal Optimization and co-editor-in-chief of the journals Applied Set-Valued Analysis and Optimization and Optimization Eruditorum, as well as a member of the editorial board of various journals.

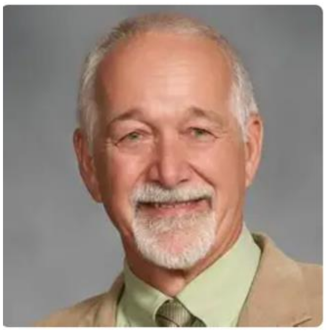
Christiane Tammer is the co-author of six monographs: Variational Methods in Partially Ordered Spaces (Second Edition), Springer Nature Switzerland, 2023; Scalarization and Separation by Translation-Invariant Functions, Springer Nature Switzerland, 2020; Approximation and Nonlinear Optimization in Practical Problems (in German), Springer Verlag, Wiesbaden, 2017; Set-Valued Optimization: An Introduction with Applications, Springer, Berlin Heidelberg, 2015; Applied Functional Analysis (in German), Vieweg+Teubner Verlag, Wiesbaden, 2009; and Variational Methods in Partially Ordered Spaces, Springer, New York, 2003.

Keynote Talk

On Quantum Interior Point Methods

Tamás Terlaky
Lehigh University, USA

Abstract: The use of quantum computing to accelerate complex optimization problems is an exciting area of research. This presentation walks through the path from Inexact Infeasible Quantum Interior Point Methods (II-QIPMs) to Iterative Refinement (IR) enhanced Inexact Feasible QIPMs that exhibit quantum advantage and unconditional quadratic convergence of the optimality gap. These are inherently hybrid classic-quantum algorithms; they apply Quantum Linear System Algorithms (QLSAs) to solve Newton systems in QIPMs. The most sophisticated IR-IF-QIMs enjoy the best possible iteration complexity, analogous to the best exact IPMs, and allow adaptations to linear, semidefinite, and second-order conic optimization problems. The novel algorithmic scheme, instead of QLSA, allows the use of low-precision conjugate gradient methods in a classic setting, while the worst-case computational complexity is improved compared to previous IPMs. We also present some illustrative numerical results.



Prof. Terlaky has published four books, edited over ten books and journal special issues, and published over 200 research papers. Topics include theoretical and algorithmic foundations of mathematical optimization; nuclear reactor core reloading, oil refinery, VLSI design, radiation therapy treatment, and inmate assignment optimization; quantum computing.

Prof. Terlaky is Editor-in-Chief of the Journal of Optimization Theory and Applications. He has served as associate editor of ten journals and has served as conference chair, conference organizer, and distinguished invited speaker at conferences all over the world. He was the general Chair of the INFORMS 2015 Annual Meeting, a former Chair of INFORMS' Optimization Society, Chair of the ICCOPT Steering Committee of the Mathematical Optimization Society, Chair of the SIAM AG Optimization, and Vice President of INFORMS. He received the MITACS Mentorship Award, Award of Merit of the Canadian Operational Society, Egerváry Award of the Hungarian Operations Research Society, H.G. Wagner Prize of INFORMS, and Outstanding Innovation in Service Science Engineering Award of IISE. He is a Fellow of INFORMS, SIAM, IFORS, The Fields Institute, and elected Fellow of the Canadian Academy of Engineering. He was a Plenary Speaker at ISMP'2024 in Montreal.

Plenary Talk

Reliability Analysis of Communication Systems

Selvamuthu Dharmaraja
Indian Institute of Technology Delhi, India

Abstract: Reliability is defined to be the ability of a system or component to perform its required functions under stated conditions for a specified period of time. In the world of broadband network, different types of communication networks are facing a large demand due to its high-speed wireless data transmission, extensive coverage from base stations, and a luxury of upgrading protocol software. In this talk, an analytical model is discussed to determine reliability attributes of third generation and beyond Universal Mobile Telecommunication Systems (UMTS), Voice over Internet Protocol (VoIP), Long-Term Evolution Advanced(LTE-A), Vehicular Ad hoc Network (VANET), High-Altitude Platform (HAP) networks and Anti-UAV and UAV systems. These networks are modeled using stochastic models such as Markov chains, semi-Markov process, reliability block diagrams and Markov reward models to obtain these attributes. Numerical results illustrate the applicability of the proposed analytical model. In addition, it can help the guarantee of network connectivity after any failure, without over dimensioning the networks.

Prof. S. Dharmaraja earned his Ph.D. degree in Mathematics from the Indian Institute of Technology Madras, Chennai, in 1999. He was a post-doctoral fellow at the Department of Electrical and Computer Engineering, Duke University, USA, from 1999 to 2002. He was a research associate at the TRLabs, Winnipeg, Canada, from 2002 to 2003.

He has been with the Department of Mathematics, IIT Delhi, since 2003, where he is currently a Professor, Department of Mathematics, and joint faculty of Bharti School of Telecommunication Technology and Management since June 2013. He is a Professor (HAG) from October 2020, and he was appointed as the Institute Chair Professor from July 2019 to June 2024. During September 2020 and August 2022, July 2014 and August 2017, he served as Head, Department of Mathematics. He was appointed as Jaswinder & Tarvinder Chadha Chair Professor for teaching and research in the area of Operations Research from May 2010 to July 2015. He has held visiting positions at the New York University, USA, Duke University, USA, Emory University, USA, University of Calgary, Canada, University of Los Andes, Bogota, Colombia, National University of Colombia, Bogota, Colombia, University of Verona, Verona, Italy, Sungkyunkwan University, Suwon, Korea, Universita degli Studi di Salerno, Fisciano, Italy and University of New South Wales, Sydney, Australia.

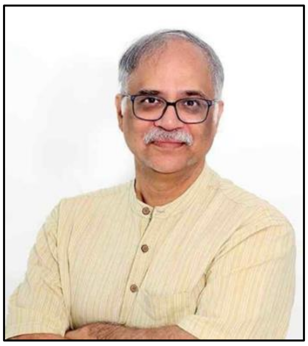
His research interests include applied probability, queueing theory, stochastic modeling, performance analysis of computer and communication systems and financial mathematics. He has published over 110 papers in refereed international journals and over 50 papers in refereed international conferences in these areas. He is an Associate Editor of the International Journal of Communication Systems (published by Wiley) and a Managing Editor of Opsearch (published by Springer). He is also the author of several textbooks.

Plenary Talk

Primal-Dual Linear Programs: A View Through Variational Inequalities

Joydeep Dutta
Indian Institute of Technology Kanpur, India

Abstract: We study primal–dual linear programming problems through the framework of variational inequalities and linear complementarity theory. By reformulating the classical primal–dual pair as a monotone variational inequality over the nonnegative orthant, we establish an explicit connection between optimal solutions and the solution set of an associated variational inequality. We apply the Korpelevich extragradient method to solve the primal–dual problem and semidefinite programming problems.



Prof. Joydeep Dutta is a Professor in the Department of Economic Sciences at the Indian Institute of Technology Kanpur, where he has been a faculty member since May 2017. He previously served as the Founder Head of the Department of Economic Sciences from 2017 to 2019. His academic career at IIT Kanpur spans over two decades, during which he has held various positions, including Professor and Associate Professor of Mathematics. Prior to his tenure at IIT Kanpur, he served as an Assistant Professor at IIT Kharagpur. He also holds industrial experience, having worked as a Software Engineer at Complete Business Solutions Inc. early in his career.

His primary research interests lie in Optimization Theory, with specific expertise in convex and nonsmooth optimization, vector optimization, and bilevel programming. More recently, his work has expanded into applications of optimization in economics and engineering, specifically focusing on multi-leader follower games, Generalized Nash Equilibrium, and the study of option pricing under rough volatility. Prof. Dutta has a prolific publication record in leading journals such as the Journal of Optimization Theory and Applications, Mathematical Programming, and Annals of Operations Research. He has also co-authored several books, including Principles of Optimization Theory and Optimality Conditions in Convex Optimization: A Finite Dimensional View. In addition to his research, Prof. Dutta has been actively involved in academic leadership and project management. He has led several sponsored research projects funded by agencies such as the Science and Engineering Research Board (SERB) and the Department of Science and Technology (DST). His contributions to the academic community include serving as a reviewer for Mathematical Reviews of the American Mathematical Society and acting as a referee for numerous prestigious journals, including the Journal of Mathematical Analysis and Applications, Journal of Global Optimization, and Numerical Functional Analysis and Optimization. He also served on the editorial board of the International Journal of Modern Mathematics from 2006 to 2008.

Plenary Talk

Knowledge Graph-Augmented Stacking for Accurate Bike-Sharing Demand Forecasting: The RideGraph Framework

Adrijit Goswami
Indian Institute of Technology Kharagpur, India

Abstract: Accurately forecasting bike-sharing demand is vital for improving service reliability, reducing operational costs, and supporting sustainable urban transportation. Existing models often fail to capture the nonlinear and spatio-temporal dependencies present in real-world data, resulting in limited generalization and inconsistent performance. This study presents two complementary predictive models that integrate knowledge graph features with ensemble and deep learning techniques to address these challenges. The first model, RideFusionWeights, combines five machine learning algorithms: Random Forest, Extra Trees, XGBoost, LightGBM and Gradient Boosting, using an optimized weighted ensemble strategy that minimizes prediction error. The second model, RideGraph-ANN Stack, extends this framework by employing an artificial neural network as a meta-learner to stack and refine the ensemble outputs, enabling the model to capture higher-order nonlinear relationships. Both models utilize knowledge graph features extracted from a knowledge graph built on the Seoul Bike Sharing Demand Prediction dataset, Experimental results show that RideGraph-ANN Stack achieved the best performance, with a mean absolute error of 70.81, mean squared error of 17,571.75, root mean squared error of 132.56, and a coefficient of determination of 0.958, outperforming all baseline regressors by roughly ten percent. These results demonstrate that integrating knowledge graph features with ensemble and neural stacking methods provides a scalable and effective framework for accurate bike-sharing demand prediction.

Prof. Adrijit Goswami is a Professor (HAG) in the Department of Mathematics at the Indian Institute of Technology Kharagpur, where he has served as a faculty member since April 1992. He currently serves as the Head of the Department of Mathematics, a position he also held from October 2023 to 2024. Prof. Goswami earned his Ph.D. in Mathematics from Jadavpur University in 1992, following the completion of his Master of Science at the same institution in 1985. His academic career at IIT Kharagpur has included significant administrative leadership positions, such as Dean of Continuing Education, Chairman of the Hall Management Committee, and Chairman of the IIT Joint Entrance Examination (JEE) in 2014 and 2015.

His research spans both Mathematics and Computer Science, with major interests in Operations Research, Supply Chain Management, Fuzzy Mathematics, Big Data

Analysis, and Cryptography and network security. Prof. Goswami has a distinguished publication record with over 190 research papers in international and national journals and conferences, accumulating more than 7,300 citations with an h-index of 44. He has successfully guided 26 doctoral students and over 85 postgraduate students. Beyond his research and teaching, he has managed sponsored and consultancy projects valued at over 20.00 Crores, including high-impact initiatives like the “Software for Managing Institutes of Learning and Education” funded by the World Bank and the UKIERI SPARC support program sponsored by the British Council.

Prof. Goswami is actively involved in the global academic community through his editorial contributions and national-level responsibilities. He serves as an Associate Editor for Sadhana and the International Journal of Applied and Computational Mathematics, and is a member of the editorial boards for the International Journal of Fuzzy and Rough Systems and the International Journal of Mathematics in Operational Research. Nationally, he has served as the Group Coordinator for the Global Initiative of Academic Network (GIAN) and as Joint PI for the Scheme for Promotion of Academic and Research Collaboration (SPARC). He is also a member of professional bodies such as the Operational Research Society of India (ORSI) and the Indian Society of Theoretical and Applied Mechanics (ISTAM).

Plenary Talk

Optimality and duality aspects for semi-infinite programming problems having disjunctive constraints

S. K. Gupta
Indian Institute of Technology Roorkee, India

Abstract: An optimization problem involving a finite number of variables and an infinite number of constraints is known as a semi-infinite optimization problem. Over the past decade, optimality and duality theorems for such problems have attracted significant attention, not only because of their rich structural properties but also due to their wide-ranging applications in engineering, production, marketing, finance, management, robotics, and related fields. In this talk, I focus on the optimality and duality aspects of multiobjective semi-infinite programming problems with disjunctive constraints. I begin by introducing a semi-infinite optimization model with cone constraints and then discuss the necessary optimality condition using the limiting constraint qualification for the considered problem. Subsequently, I discuss the notion of quasiconvexity over cones, followed by the sufficient optimality conditions under generalized convexity and generalized Q-convexity assumptions. Furthermore, Mond–Weir and Wolfe-type dual problems are presented, and usual duality results between the semi-infinite optimization model and its corresponding dual problems are shown under generalized convexity and generalized Q-convexity assumptions. Finally, I discuss optimality conditions for multiobjective semi-infinite equilibrium problems with vanishing constraints and with uncertain data, along with the associated duality results, and illustrate the applicability of the proposed framework through a multiobjective transportation problem.

Prof. S. K. Gupta received his Ph.D. in Optimization Theory from the Indian Institute of Technology Roorkee, India, in 2008. He joined Thapar University, Patiala in 2006, Indian Institute of Technology Patna in 2008 and subsequently moved to the Indian Institute of Technology Roorkee in 2012 as an Assistant Professor. He is currently a Professor in the Department of Mathematics at the Indian Institute of Technology Roorkee, India.

He has published over 70 research articles in reputed international journals. His research interests include optimization theory, non-smooth optimization, support vector machines, and optimization under uncertainty. He has supervised 11 Ph.D. theses so far and is currently supervising five Ph.D. theses. He has also received the Best Teacher Award from the Indian Institute of Technology Patna in 2010, Prof. Bal Krishna Outstanding Teacher Award at IIT Roorkee in 2022, and Bestowal of Excellence in Teaching Award (UG category) at IIT Roorkee in 2024. He has completed and is currently involved in several sponsored research projects, including ANRF-MATRICS and NBHM.

He has also developed five NPTEL courses: Mathematical Methods and Its Applications (with Prof. P. N. Agrawal), Nonlinear Programming, Multivariable Calculus (with Prof. Sanjeev Kumar), Matrix Analysis with Applications (with Prof. Sanjeev Kumar), and Essential Mathematics for Machine Learning (with Prof. Sanjeev Kumar).

Plenary Talk

Modified penalty function method for controlled multi-dimensional optimization problems

Anurag Jayswal
Indian Institute of Technology (Indian School of Mines), Dhanbad, India

Abstract: This talk presents an auxiliary method for addressing the multi-time control optimization problem with first-order PDE constraints. For this, two approaches have been used, namely the penalty function method and the modified objective function method. First, the considered constrained problem is penalized to construct an associated unconstrained optimization problem, and then an equivalence between the solutions of the constrained and penalized problems is established. After that, the original problem is then linearized using a modified objective function technique, which significantly reduces the complexity of the objective functional while maintaining optimality. Subsequently, the modified problem is further penalized using the absolute value exact penalty function technique, and it is shown that the minimizer of the resulting modified unconstrained problem coincides with the solution of the original problem under suitable hypothesis. Also, some examples are provided to validate the theoretical results.

Prof. Anurag Jayswal is a Professor at the Department of Mathematics and Computing in Indian Institute of Technology (ISM) Dhanbad, where he has been a faculty member since August 2010. Before joining IIT (ISM) Dhanbad, he served as an Assistant Professor at the Birla Institute of Technology, Ranchi, and held a research fellowship at G. B. Pant University of Agriculture and Technology. Prof. Jayswal earned his Ph.D. from Banaras Hindu University (BHU) in 2002.

His research expertise encompasses Mathematical Programming, Vector Optimization, Variational Inequality, and Robust Optimization. With over 75 SCI/ESCI-indexed publications, his recent work has appeared in high-impact journals such as the Annals of Operations Research, Optimization, and the Journal of Computational and Applied Mathematics. He has also served as an editor for books published by Springer and CRC Press, including Multi-dimensional Control Problems: Robust Approach and Continuous Optimization and Variational Inequalities. Prof. Jayswal has successfully managed several significant sponsored research projects, including a 2022–2025 study on multi-time control problems funded by SERB-DST and earlier projects supported by CSIR, UGC, and DST.

Prof. Jayswal is actively engaged in the broader scientific community, serving as an editorial board member for Opsearch (Springer) and Advances in Nonlinear and

Variational Inequality. He has acted as a referee for numerous prestigious journals, including the European Journal of Operational Research, Information Sciences, and the Journal of Global Optimization. In addition to his research, he has held various administrative roles at IIT (ISM) Dhanbad, currently serving as Associate Dean (SIW) and Time Table Incharge. His international academic presence is marked by visits to institutions such as Imperial College London, the University of Florida, and Heidelberg University

Plenary Talk

Bivariate Semi-Parametric Model: Construction and Inference

Debasis Kundu
Indian Institute of Technology Kanpur, India

Abstract: The motivation of this work from two bivariate diabetic retinopathy data sets. The main aim is to test whether the laser treatment delays the onset of blindness compared to the traditional treatment. The first data set is of 197 patients and it provides the onset of blindness of the two eyes. The observed data are heavily censored on both the variables. The second data set is of 91 patients, and it indicates the minimum time of the onset of blindness between the two eyes. In both the cases there is a significant proportion where the onset of blindness has occured on both the eyes simultaneously, i.e. there is a significant proportion where both the variables are equal. Hence, the two variables cannot be treated as independent. We have used a Marshall-Olkin bivariate exponential or Weibull type a bivariate semi-parametric model, where the base line distribution is more flexible than any parametric distribution. The base line distribution is assumed to have a piecewise constant hazard function and that makes the Bayes line hazard function to be very flexible. We have considered both the classical and Bayesian inference of the un known parameters. Finally, both the data sets have been analyzed, and it is observed for one data set the laser treatment has a significantly different effect than the traditional treatment, where as for the other data set no significantly different effect has been observed.

Prof. Debasis Kundu received his B.Stat and M.Stat from the Indian Statistical Institute in 1982 and 1984, respectively, and Ph.D. from the Pennsyl vania State University in 1989 under the guidance of Professor C. R. Rao. After finishing his Ph.D. he joined the University of Texas at Dallas as an Assistant Professor before joining Indian Institute of Technology Kanpur in 1990. He served as the Head of the Department of Mathematics and Statistics, IIT Kanpur from 2011 to 2014 and the Dean of Faculty Affairs at IIT Kanpur from 2019 to 2022. Prof. Kundu is holding an Endowed Chair Professor post of the Institute since 2008.

Prof. Kundu works on different areas of Statistics. His major research interests are on Statistical Signal Processing, Lifetime Data Analysis and Statistical Computing. He has published more than 400 research papers in different well reputed Statistical and Signal Processing journals like IEEE Transaction on Signal Processing; Signal Processing; Circuits, Systems and Signal Processing; Technometrics; Annals of the Institute of Statistical Mathematics; Statistica Sinica; Scandinavian Journal of Statistics;

Journal of Multivariate Analysis; Computational Statistics and Data Analysis; Journal of Statistical Planning and Infer ence; IEEE Transactions on Reliability etc.
His work has been well cited by different researchers. He has more than 22,500 google scholar citations with h index 69. He has co-authored three books on Statistical Signal Processing and lifetime data analysis and co-edited one book on Statistical Computing. He is a Fellow of the National Academy of Sciences, India, and a Fellow of the Indian Society of Probability and Statistics. He has received the Distinguished Teacher's Award from IIT Kanpur, Distinguised Statistician's Award from the Indian Society of Probability and Statistics and Professor P.C. Mahalanobis Distinguished Educator's Award by the Operation Society of India. He is currently the Editor-in-Chief of the Journal of the Indian Society of Probability and Statistics, and on the editorial boards of Sankhya, Ser. B, Indian Journal of Pure and Applied Mathematics, Journal of Statistical Theory and Practice and Applied Stochastic Models in Business and Industry.

Plenary Talk

Quantum optimization algorithms and Their Impact on Cyber Security

Bhupendra Singh
Scientist F, CAIR, DRDO Bangalore, India

Abstract: Optimization is a central feature of decision-making problems because it exists in a broad range of scientific, finance, industrial and technological applications. Classical optimization algorithms work on traditional (classical) computers using bits (0 and 1). To overcome these difficulties, quantum computers are used that allows exploring many possible solutions in parallel, making them faster and more efficient. Quantum computers use qubits, which can represent both 0 and 1 at the same time through quantum superposition and can interact through quantum entanglement. In this talk I will introduce qubits, single qubit quantum gates, two qubits quantum gates, three qubit quantum gates, quantum superposition, quantum entanglement and their matrix equivalence. The Grover's search quantum algorithm will be presented as quantum optimization algorithm which optimises the amplitude of the states. The impact of Grover's search quantum algorithm on cyber security will also be discussed. Future direction for the research on quantum computing will also be indicated.

Dr. Bhupendra Singh is an alumnus of Allahabad University, IIT Madras, and Masaryk University, Brno, Czech Republic. He joined DRDO as a Scientist-B in 2005 and is currently working as a Scientist-F at the same organization.

His areas of research include the design and analysis of symmetric key cryptographic algorithms, the design and analysis of quantum-safe symmetric and asymmetric key cryptographic algorithms, the analysis of quantum random number generators, design and analysis of quantum algorithms and construction of cryptographically significant Boolean functions and S-Boxes.

He was a panellist at VAIBHAV-2020 in the Quantum Technology Vertical, organized by the PMO. Dr. Singh has been an elected executive committee member of the Cryptology Research Society of India since 2015. He has published more than 30 research papers in national and international, conferences and journals. He has filed five Indian patents and holds one copyright in the area of cybersecurity and quantum algorithms. His is author of book titled "Quantum Algorithms and their Applications in Cryptology: A Practical Approach" with CRC Press and editor of book title "Sensor Technologies and Wireless Communications in Industry 5.0: A Solution for Smart Manufacturing".

Plenary Talk

Optimality conditions for sharp and isolated solutions in nonsmooth optimization

Radu Strugariu
Gheorghe Asachi Technical University of Iasi, Romania

Abstract: In this talk, we present some sufficient optimality conditions for sharp and isolated solutions of constrained scalar and set-valued nonsmooth optimization problems, formulated in terms of several types of subgradients and coderivatives. By assuming Shapiro properties for the constrained set and employing different types of generalized differentiation objects, we are able to describe multiple degrees of sharpness. The main results extend and generalize related findings from the literature.

Prof. Radu Strugariu is a Romanian mathematician and Professor in the Department of Mathematics and Computer Science at the Gheorghe Asachi Technical University of Iași.

He earned his Ph.D. in 2009 under the supervision of Constantin Zălinescu. Since then, he developed research activity in the fields of variational analysis, set-valued optimization, vector optimization, and nonsmooth analysis. As notable professional landmarks, we mention: the study of the incompatibility principle between openness and optimality in the framework of set-valued optimization, results concerning the regularity of set-valued mappings of sum and composition type, investigation of the directional regularity of mappings using minimal time function, a unified optimization theory for variable domination structures. Through his research, teaching, and international collaborations, Radu Strugariu contributes to the mathematical foundations of modern optimization theory.

Plenary Talk

Penalty-Based Constrained Bayesian Optimization

Neelesh S. Upadhye
Indian Institute of Technology Madras, Chennai, India

Abstract: This work develops a practical framework for constrained Bayesian optimization (BO) when both the objective and constraints are expensive black-box functions and the feasible set is unknown. The central idea is to incorporate constraints directly into BO by multiplying any standard acquisition function (e.g., Expected Improvement or UCB) with a probabilistic feasibility penalty, typically the probability that all constraints are satisfied under Gaussian process surrogate models. This yields a penalized acquisition that automatically trades off objective improvement against feasibility, suppressing evaluations in regions predicted to be infeasible while still exploring uncertain boundary areas that may contain feasible optima. The framework is instantiated for multiple acquisition strategies (including EI, UCB, probability-of-feasibility phases, and Thompson sampling), and an end-to-end algorithmic procedure is provided, covering initialization, acquisition maximization, model updates, and handling cases where feasible points are initially absent. Theoretical discussion argues that the penalty-augmented approach retains convergence and no-regret characteristics under standard GP assumptions, with behaviour approaching unconstrained BO on the learned feasible region. Empirical studies across benchmark classes—engineering design (tension spring), synthetic tiny-feasible-region problems, constrained hyperparameter tuning, environmental control (pump-and-treat hydrology), and additional ML tuning examples- show improved sample efficiency and substantially reduced wasted evaluations compared to unconstrained baselines, while remaining simple to implement and adaptable to varied constraint regimes.

Prof. Neelesh S. Upadhye is a Professor in the Department of Mathematics at the Indian Institute of Technology Madras. He earned his Ph.D. in Mathematics from IIT Bombay in 2009. His primary research interests include Applied Probability, Stein's Method, Statistical Learning, Subordinated Stochastic Processes, and Time Series. Prof. Upadhye has a significant record of scholarly publications in journals such as Technometrics, Statistics & Probability Letters, and Statistical Methods & Applications, focusing on areas like Bayesian optimization, tempered stable distributions, and financial time series forecasting.

In addition to his research, Prof. Upadhye is actively involved in high-impact projects and academic leadership. He is the Principal Investigator for an ongoing project on "Computational Mathematics and Data Science" funded by the Ministry of Education (2021–2026) and serves as a retainer consultant for PDSVISION on shape-based search algorithms. He has successfully supervised several doctoral theses covering topics such as Stein's method for stable distributions, Bayesian statistics in finance, and fractal interpolation. His recent teaching portfolio at IIT Madras includes courses on "Stochastic Methods in Industry" and "Data Analysis & Visualization" using R, Python, and SQL.

Plenary Talk

On the conditional Independence of Bernoulli random variables

Palaniappan Vellaisamy
UC Santa Barbara, California, USA

Abstract: In this talk, we will discuss some simple sufficient conditions for checking the conditional independence of three Bernoulli random variables. Also, we present an easy-to-use algorithm to construct a joint distribution having the conditional independence structure. The relations between the marginal independence and the conditional independence are analyzed in detail. The results and the conditions are quite simple and hence will be useful to the teachers, students and the researchers interested in statistics, probability and computer science. Applications to the analysis of a graphical model and a causal inference design are also discussed.

Prof. P. Vellaisamy is a Visiting Professor at UC Santa Barbara, California, USA. He was a former Professor in the Department of Mathematics at the Indian Institute of Technology Bombay, where he has been a faculty member since 1991. He earned his Ph.D. in Statistics from IIT Kanpur in 1989, following an M.Sc. from Annamalai University, where he secured the university rank and was awarded the Professor V. Baliah Gold Medal. He has also held several prestigious visiting positions globally, including serving as a Visiting Professor at Michigan State University, University of Mainz, and NCVC Research Institute in Japan.

His research expertise spans Applied Probability, Statistical Inference, Industrial Statistics, and Fractional Stochastic Processes, with specific interests in distribution theory, categorical data analysis, and probability approximations. Professor Vellaisamy has published over 120 research papers in well-regarded international journals such as the Journal of Statistical Planning and Inference, IEEE Transactions on Information Theory, Communications in Statistics, and Journal of Applied Probability. His scholarly contributions have earned him numerous distinctions, including being an elected Fellow of the National Academy of Sciences (NASI), India, and an elected member of the International Statistical Institute (ISI), Netherlands. He was recently honored with the Prof. K.S. Rao Best Researcher Award (2022) by the Indian Society for Probability and Statistics.

Prof. Vellaisamy has managed multiple significant sponsored research projects funded by national agencies, including projects on “Measures of association and their

A-collapsibility" and "Reliability test plans" funded by the Department of Science and Technology (DST), as well as CSIR-sponsored work on sampling plans for production processes. In the editorial realm, he serves as an Associate Editor for the Mathematical Methods of Statistics (Springer) and the American Journal of Mathematical and Management Sciences (Taylor and Francis). He has acted as an editor for the International Journal of Applied Mathematics and Statistics and has performed referee duties for prestigious journals such as Naval Research Logistics, Statistical Papers, and Statistics & Probability Letters. He is a life member of several professional bodies, including the Indian Society for Probability and Statistics (ISPS) and the Indian Statistical Association (ISA).

Throughout his career, Prof. Vellaisamy has been an active participant in global academic discourse, delivering invited talks and presenting at conferences such as the ISPS Annual Conventions, IISA International Conferences, and various seminars at institutions like Keio University, University of Heidelberg, and McMaster University.

Plenary Talk

Duality theory in IF Mathematical Programming Problems

Shiv Prasad Yadav
Indian Institute of Technology Roorkee, India

Abstract: In this talk, the following topics will be discussed: some basic definitions and concepts, decision making in IFE, duality in IF programming under pessimistic approach, duality in IF programming under optimistic approach, duality in IF programming under mixed approach, some numerical examples, followed by concluding remarks.

Prof. Shiv Prasad Yadav is a distinguished academician and Visiting Professor at the Indian Institute of Technology Roorkee, where he has served in various capacities for nearly three decades. His career began as a Lecturer at BITS Pilani in 1986, followed by a long-standing tenure at IIT Roorkee starting in 1996. Prof. Yadav has extensive teaching experience spanning 38 years and has held the rank of Professor since 2012.

His research contributions are significant, with 102 papers published in journals and 39 papers in conference proceedings. He is particularly noted for his work in fuzzy data envelopment analysis and optimization, including the book chapter "Fuzzy Mix-efficiency in Fuzzy Data Envelopment Analysis and its Application" published by Springer in 2014. His scholarly impact is reflected in over 3,000 Google Scholar citations and an h-index of 32. Prof. Yadav's excellence in research was recognized with the I. H. Kencharaddi prize from the Indian Water Works Association for his work on the optimization of water distribution systems.

In addition to his research, Prof. Yadav has been a prolific mentor, supervising 20 Ph.D. theses, 7 M.Phil. theses, and 95 M.Sc. theses. He is a frequently invited speaker at prestigious institutions across India, including IIT BHU, IIM Ahmedabad, and various National Institutes of Technology (NITs). His professional service includes hosting invited talks at over 25 major universities and institutes, underscoring his influence in the fields of mathematics and operations research.

Invited Talk

Dependence and Uncertainty: Information Measures using Tsallis Entropy

Mohd. Arshad (Joint work with S. G. Zachariah and A. K. Pathak)
Indian Institute of Technology Indore, India

Abstract: In multivariate analysis, uncertainty arises from two sources: the marginal distributions of the variables and their dependence structure. Quantifying the dependence structure is crucial, as it provides valuable insights into the relationships among components of a random vector. Copula functions effectively capture this dependence structure independent of marginals, making copula-based information measures highly significant. However, existing copula-based information measures, such as entropy, divergence, and mutual information, rely on copula densities, which may not exist in many scenarios, limiting their applicability. In this work, we introduce copula-based measures using Tsallis entropy, a non-additive entropy that offers greater flexibility for quantifying uncertainty. We propose cumulative copula Tsallis entropy, derive its properties and bounds, and illustrate its utility through examples. We further develop a non-parametric version of the measure and validate it using coupled periodic and chaotic maps. Additionally, we extend Kerridge's inaccuracy measure and Kullback Leibler (KL) divergence to the cumulative copula framework. By leveraging the relationship between KL divergence and mutual information, we propose a new cumulative mutual information (CMI) mea sure that addresses the limitations of density-based mutual information. Furthermore, we introduce a test procedure for testing the mutual independence among random variables using the CMI measure. Finally, we illustrate the potential of the proposed CMI measure as an economic indicator through real bivariate financial time series data.

Dr. Mohd. Arshad is an Associate Professor in the Department of Mathematics at the Indian Institute of Technology Indore. He earned his Ph.D. in Statistics from IIT Kanpur in 2015 under the guidance of Prof. Neeraj Misra. His primary research expertise lies in Statistical Inference, with a focused interest in Selection and Ranking problems and Estimation after Selection. Dr. Arshad has a prolific

publication record in esteemed journals such as Statistical Papers, Statistical Methodology, and the Journal of Statistical Theory and Practice, where he often investigates the nuances of selecting best populations under constraints such as unequal sample sizes.
He is a Life Member of the Indian Society of Probability and Statistics (ISPS). Dr. Arshad's research has been supported by significant national grants; he is currently the Principal Investigator for a SERB-DST MATRICS project on the simultaneous estimation of parameters after selection and previously completed a SERB-DST Early Career Research (ECR) project.

In addition to his research and teaching, Dr. Arshad serves the academic community as a reviewer for various international journals in statistics and probability. Throughout his career, he has actively participated in and presented his findings at several significant academic gatherings, including the XXXIV Annual Convention of the Indian Society for Probability and Statistics (ISPS) and the International Conference on Statistics and Information Technology for a Better Tomorrow.

Invited Talk

Covariance identities and variance bounds for infinitely divisible random variables and their applications

Kalyan Barman (joint work with Neelesh S. Upadhye and P. Vellaisamy)
National Institute of Technology Warangal, Telangana, India

Abstract: In this talk, we establish a general covariance identity for infinitely divisible distributions. Using this result, we derive Cacoullos type variance bounds for the infinitely divisible distributions. Applications to some important distributions are discussed, in addition to the computation of variance bounds for certain posterior distributions. As another application, we derive the Stein-type identity for the infinitely divisible distributions, which involves the Lévy measure. This result in turn is used to derive the Stein-type identity for the CGMY distributions and the variance-gamma distributions. This approach, especially for the variance-gamma distributions, is new and simpler, compared to the ones available in the literature. Finally, as another nontrivial application, we apply the covariance identity in deriving known and some new formulas for the weighted premium calculation principles and Gini coefficient for the infinitely divisible.

Dr. Kalyan Barman is an Assistant Professor in the Department of Mathematics at the National Institute of Technology (NIT) Warangal, a position he has held since August 2025. He earned his Ph.D. in Mathematics from the Indian Institute of Technology Madras in 2023 under the supervision of Prof. Neelesh S. Upadhye, with a thesis titled "Stein's Method for Stable and Tempered Stable Distributions".

His research expertise lies in Applied Probability and Statistics, with specific interests in Stein's method, Malliavin-Stein techniques, stable and tempered stable distributions, and limit theorems. Dr. Barman has published several papers in reputed journals, including Statistics & Probability Letters, Probability Surveys, and Modern Stochastics: Theory and Applications. His research portfolio includes a unified approach to Stein's method for stable distributions and the study of Brascamp-Lieb and Poincaré type inequalities.

Before joining NIT Warangal, Dr. Barman gained significant research experience as an Institute Postdoctoral Fellow at IIT Bombay (2023–2025) and briefly as a Research Associate-II at IISER Bhopal. He has also served as a Teaching Assistant for various courses at IIT Madras and IIT Bombay, covering topics such as Probability, Statistical Inference, and Stochastic Methods in Industry.

Invited Talk

Generalized Multi-Inertial Splitting Methods for Solving Inclusion Problems

Prasit Cholamjiak
University of Phayao, Phayao, Thailand

Abstract: In this research, we introduce a new modification of proximal gradient algorithms for the inclusion problem. Our method is based on multi-inertial extrapolations and self-adaptive technique which can eliminate the Lipschitz assumptions of the gradient of functions and increase the speed of convergence behavior of the proposed method. We also establish a weak convergence theorem under mild conditions. Finally, we apply our method to image restoration problem.

Dr. Prasit Cholamjiak is a distinguished mathematician at the Department of Mathematics, School of Science, University of Phayao, Thailand. He earned his Ph.D. in Mathematics from Chiang Mai University in 2011 and has steadily progressed through academic ranks since beginning his career as a lecturer in 2004. His research focuses on optimization theory and algorithms, fixed point theory, variational inequalities, and applications of optimization techniques in data classification, signal processing, and image restoration. Over the years, he has built an outstanding international research profile, serving on the editorial board of the Thai Journal of Mathematics and receiving multiple competitive research grants, including the Royal Golden Jubilee Research Fellowship and the TRF Research Career Development Grant. He was recognized among the World's Top 2% Scientists in 2022 and 2023 and received the UP Outstanding Research Award in Science and Technology (2019–2020).

Dr. Cholamjiak has made significant contributions to nonlinear analysis and optimization, authoring more than 170 indexed publications with a strong citation impact (Google Scholar h-index 31 and over 3000 citations). His recent work centers on inertial and proximal-type algorithms for solving monotone variational inequalities, equilibrium problems, and convex optimization models with applications to image processing and data science. He has been an invited speaker at numerous international conferences across Asia and Europe, reflecting his global research collaborations and academic leadership. Proficient in LaTeX, MATLAB, and Python, he actively integrates computational tools into both his research and teaching, contributing substantially to the advancement of modern optimization methods and their real-world applications.

Invited Talk

A Fixed Point Optimization Framework for Extreme Learning Machine with Applications to Medical Data Classification

Watcharaporn Cholamjiak
University of Phayao, Phayao, Thailand

Abstract: This study presents a mathematical and algorithmic framework integrating extreme learning machine (ELM), fixed point theory, and optimization methods for machine learning applications. First, the mathematical formulation of a single-layer extreme learning machine is introduced and systematically extended to a multi-layer extreme learning machine structure to enhance representational capability and learning performance. The study further investigates iterative algorithms for nonexpansive mappings in Hilbert spaces and establishes new convergence conditions for a countable family of mappings. These theoretical developments provide a unified analytical framework connecting fixed point theory with various optimization problems. Moreover, the relationship between fixed point algorithms and optimization techniques

is explored, highlighting their practical relevance in applications such as image restoration, signal recovery, and machine learning. Based on this theoretical foundation, fixed point algorithms are applied to determine the optimal output weights of machine learning models, particularly for classification tasks in medical datasets. The proposed framework bridges mathematical theory and practical machine learning implementation, offering both theoretical convergence guarantees and effective computational methods for solving optimization-based learning problems in real-world medical data analysis.

Dr. Watcharaporn Cholamjiak is a faculty member in the Department of Mathematics, School of Science, University of Phayao, Thailand. She earned her B.S., Graduate Diploma in Teaching Profession, and M.S.-Ph.D. in Mathematics from Chiang Mai University, completing her doctoral degree in 2011 with a thesis on strong convergence theorems for common fixed points of generalized quasi-nonexpansive mappings. She joined the University of Phayao as a Lecturer in 2015, was promoted to Assistant Professor in 2017, and became Associate Professor in 2020. Her research interests include optimization algorithms, fixed point theory, data analysis, machine learning, image restoration, and signal recovery. She is the author of the book *Fixed Point Optimization Algorithms and Their Applications* (Morgan Kaufmann, 2024) and serves in several editorial roles, including Lead Guest Editor and Academic Editor for international journals.

Dr. Cholamjiak has established an impressive international research profile with over 100 refereed publications indexed in major databases (Scopus h-index 15; Google Scholar h-index 18, with more than 1,100 citations). Her recent work focuses on inertial and forward–backward splitting algorithms for variational inclusion and equilibrium problems, with impactful applications in medical diagnosis, disease prediction, image processing, and artificial intelligence. She has delivered invited talks and participated in numerous international conferences across Asia and Europe and actively collaborates with researchers worldwide. Through her contributions to nonlinear analysis and optimization-based machine learning methods, she continues to advance both theoretical foundations and practical applications in mathematical sciences.

Invited Talk

Learning Feasible Region with Optimistic Constraint Exploration

Raju Chowdhury
Indian Statistical Institute Kolkata, India

Abstract: Feasible Region Identification concerns determining the set of decision variables that satisfy a collection of constraints when those constraints are unknown or

expensive to evaluate. This problem requires learning the constraints while maintaining feasibility during the search, even though infeasible evaluations may still contain useful information. The proposed method reformulates constraints to explicitly account for infeasibility and leverages this information for learning. Surrogate models are employed to approximate the constraint functions and are updated iteratively as new observations are collected. An optimistic sampling policy actively guides evaluations toward regions that reduce uncertainty about feasibility while prioritizing constraint satisfaction. The approach is assessed on several benchmark problems and real-world applications, demonstrating improved efficiency in identifying feasible regions under limited evaluation budgets and complex constraint settings.

Dr. Raju Chowdhury is a Research Associate-I in the SQC & OR Unit at the Indian Statistical Institute (ISI) Kolkata. He earned his Ph.D. in Mathematics from the Indian Institute of Technology Madras in December 2024, specializing in "Bayesian Optimization with big-M Penalty for Constrained Problems". His academic background includes an M.Tech. in Industrial Mathematics & Scientific Computing from IIT Madras and a B.Sc. in Mathematics from the University of Burdwan, where he graduated with first-class honors.

His primary research expertise lies in Bayesian Optimization, surrogate modeling, Gaussian processes, and statistical learning. His work addresses complex optimization challenges, such as constrained Bayesian optimization using improvement-based policies and big-M penalty methods. He has also served as a reviewer for prestigious journals and conferences, including Technometrics and the International Conference on Artificial Intelligence and Statistics (AISTATS).

Throughout his career, Dr. Chowdhury has actively participated in high-level academic forums and professional development. He served as a Session Chair at the 2026 International Conference for Supply Chain Modelling, Optimization, Digitalization & Analytics at ISI Kolkata. His conference presentations include work delivered at HTW Berlin, Germany, and the Chennai Mathematical Institute. Furthermore, he has completed specialized training in Bayesian estimation for robotics and stochastic processes for data science at IIT Madras.

Invited Talk

Relocated fixed-point iterations with applications to variable stepsize resolvent splitting.

Minh Dao
RMIT University, Australia

Abstract: In this work, we develop a convergence framework for iterative algorithms whose updates can be described by a one-parameter family of nonexpansive operators.

Within the framework, each step involving one of the main algorithmic operators is followed by a second step which "relocates" fixed-points of the current operator to the next. As a consequence, our analysis does not require the family of nonexpansive operators to have a common fixed-point, as is common in the literature. Our analysis uses a parametric extension of the demiclosedness principle for nonexpansive operators. As an application of our convergence results, we develop a version of the graph-based extension of the Douglas--Rachford algorithm for finding a zero of the sum of maximally monotone operators, which does not require the resolvent parameter to be constant across iterations.

Dr. Minh N. Dao received the Ph.D. degree in applied mathematics from the University of Toulouse, France. He is currently a Senior Lecturer at RMIT University, Australia. Previously, he was a Lecturer at Hanoi National University of Education, Vietnam; a Postdoctoral Fellow at The University of British Columbia, Canada; a Research Associate at The University of Newcastle and The University of New South Wales, Australia; and a Lecturer at Federation University, Australia. His research interests include mathematical optimization, convex and variational analysis, operations research, and machine learning. He has received the Journal of Global Optimization Best Paper Award and the Springer Nature Editor of Distinction Award. He also serves as an Associate Editor for several international journals including Set-Valued and Variational Analysis (Springer) and Optimization (Taylor & Francis).

Invited Talk

Modelling Correlated Bivariate Data in The Presence of Inliers

Ishapathik Das (joint work with Sumangal Bhattacharya)
Indian Institute of Technology Tirupati, India

Abstract: Lifetime and reliability data from life testing experiments, clinical trials electronic component testing, rainfall measurements, and insurance claims often include zero or near zero observations, commonly called inliers or instantaneous failures, which classical unimodal lifetime models such as the Weibull, gamma, log normal, and Pareto distributions fail to model adequately, resulting in multimodality and biased inference. To address this problem, a Modified Weibull model is proposed

in the univariate setting, constructed as a mixture of a uniform component representing instantaneous or early failures and a Weibull distribution representing regular lifetimes, with key distributional properties derived and parameters estimated using maximum likelihood estimation combined with a density based clustering algorithm to identify inlier regions; simulation studies and real data analyses show that this model provides a substantially improved fit over existing lifetime models. Since many practical datasets are multivariate and correlated, such as paired component failures, bilateral clinical responses, or spatially correlated rainfall observations where inliers may appear in one or both variables with complex dependence, the univariate framework is insufficiet. To overcome this limitation, the approach is extended to a copula based Bivariate Modified Weibull model that allows flexible dependence modeling while accommodating inliers in each marginal distribution. The joint density, survival, and hazard functions of this model are derived, a formal testing procedure for detecting inliers is developed using the supremum of Bayes factors, and parameter estimation is carried out within a Bayesian framework using Hamiltonian Monte Carlo with the No U Turn sampler, with simulation studies and real data applications, including rainfall data, demonstrating strong finite sample performance and superior model fit compared to existing methods.

Dr. Ishapathik Das is currently positioned as Associate Professor and the Head of the Department of Mathematics and Statistics at the Indian Institute of Technology Tirupati, where he has been a faculty member since 2017. He earned his Ph.D. in Statistics from IIT Bombay in 2013, following an M.Sc. in Statistics & Informatics from IIT Kharagpur, where he was a silver medallist and ranked first in his department. His academic career includes significant international research experience as a Postdoctoral Research Associate at Duke University under the Raman Fellowship and a visiting scientist role at the Indian Statistical Institute, Delhi. He has also held a faculty position at Kumaun University and was awarded the SERB Overseas Fellowship for postdoctoral research at the University of Auckland, as well as the CICOPS Fellowship for collaborative research at the University of Pavia.

His research interests are primarily centered on Generalized Linear Models, Biostatistics, Multivariate Distributions, and Spatio-Temporal Models. Dr. Das has a robust publication record in prestigious journals, including the Journal of Statistical Planning and Inference, Journal of Applied Statistics, and Human and Ecological Risk Assessment. His work extends to practical applications such as modeling extreme events, climate data analysis, and the spatio-temporal impact of COVID-19 lockdowns on air pollution. He has successfully guided several Ph.D. and M.Sc. students in specialized areas such as advancements in space-time modeling, multivariate response models, and credit risk modeling.

Dr. Das has successfully led several sponsored research projects, including a SERB-funded project on regression models for doubly inflated multivariate count data using copulas and a UGC project on robust designs in multinomial models. He is an elected member of the Executive Committee of the Indian Society for Probability and Statistics (ISPS) and holds life memberships in both the ISPS and the Society of Statistics, Computer and Applications. His professional contributions also include organizing national conferences and workshops on geospatial data science at IIT Tirupati. Throughout his career, he has presented his research at various high-level forums, including the Bernoulli-IMS 11th World Congress in Probability and Statistics in Germany, the International Conference on Stochastic Geometry Days in France, and the 9th International Conference on Mathematics and Computing in Goa

Invited Talk

Inertial parameterized Douglas-Rachford for generalized DC programming problems

Avinash Dixit
Kirori Mal College, University of Delhi, Delhi, India

Abstract: The increasing number of applications that are modeled as nonconvex optimization problems led to the necessity of studying the latter to provide both theoretical results and viable algorithms for solving them. In this paper, we consider the difference of convex (DC) functions programming problems, one of the pillars of nonconvex programming and global optimization, more precisely, we deal with the minimization of the sum of two convex functions from which another convex function is subtracted, in a Hilbertian framework. We propose two iterative methods for solving generalized DC programming problems, an inertial Douglas Rachford DC algorithm and a parametrized Douglas Rachford DC algorithm, and study their convergence behavior. Lastly, we conduct numerical experiments to study the behavior of proposed algorithms in solving sparse recovery problems and compare the performance with already known algorithms.

Dr. Avinash Dixit is an Assistant Professor in the Department of Mathematics at Kirori Mal College, University of Delhi, where he has been serving since September 2022. He earned his Ph.D. in Mathematics from the Indian Institute of Technology (BHU), Varanasi, in 2021 under the supervision of Prof. Tanmoy Som. His doctoral research, titled "Accelerated Iterative Techniques to Solve Inclusion Problems and Applications," focused on advanced computational methods in nonlinear analysis. He completed his M.Sc. and B.Sc. from the University of Allahabad with a strong academic background. Dr. Dixit's research interests include Nonlinear Optimization, Machine Learning, and Image Processing, reflecting a blend of theoretical rigor and practical applications. Dr. Dixit has substantial teaching experience across a broad range of undergraduate courses, including Algebra, Multivariate Calculus, Numerical Analysis, Numerical Methods, and Python programming. He integrates computational tools such as Python and MATLAB into his teaching and research, and is proficient in LaTeX for academic writing. During his doctoral studies, he was awarded the Junior Research Fellowship (JRF) and Senior Research Fellowship (SRF) by IIT (BHU). He was also selected for the prestigious Labex Mathématiques Hadamard Fellowship (FMJH), France (2022–2024). Through his research and teaching, Dr. Dixit continues to contribute to the development of modern optimization techniques and their applications in data-driven sciences.

Invited Talk

Warped Yosida Regularization: Asymptotic Analysis and Applications

Pankaj Gautam (joint work with V. Vetrivel)
Indian Institute of Technology Roorkee, India

Abstract: In this talk, we introduce the notion of warped Yosida regularization and study the asymptotic behaviour of the trajectory of dynamical systems generated by warped Yosida regularization, which includes Douglas-Rachford dynamical system. We analyze an algorithm where the inclusion problem is first approximated by a regularized one and then the preconditioned regularization parameter is reduced to converge to a solution of the original problem. We propose and investigate backward-backward splitting using degenerate preconditioning for monotone inclusion problems. The applications provide a tool for finding a minima of a preconditioned regularization of the sum of two convex functions.

Dr. Pankaj Gautam is an Assistant Professor in the Department of Applied Mathematics & Scientific Computing at the Indian Institute of Technology Roorkee, a position he has held since March 2024. He earned his Ph.D. in Mathematics from the Indian Institute of Technology (BHU) Varanasi in 2021, focusing his dissertation on “Discrete and continuous dynamical systems for inclusion problems with applications” under the supervision of Prof. Tanmoy Som. Dr. Gautam brings significant international research experience to his current role, having served as an ERCIM Postdoctoral Researcher at the Norwegian University of Science and Technology (NTNU) and as an Institute Postdoctoral Researcher at IIT Madras.

His primary research interests encompass Optimization, Inverse Problems, Image Processing, and Machine Learning. Dr. Gautam has established a strong publication record in leading journals such as Optimization, Journal of Inverse and ill-posed Problems, Inverse Problems, Journal of Optimization Theory and Applications, Computational Optimization and Applications, and Optimization Methods and

Software. His recent work includes developing degenerated preconditioned backward-backward splitting for inclusion problems and parameter identification in partial differential equations. In addition to his research, he has served as a member of the program committee for the 1st and 2nd International Conference on Nonlinear Applied Analysis and Optimization at IIT (BHU) and was a co-convener for the 5th iteration of the same conference.

Dr. Gautam actively contributes to academic administration and community engagement, currently serving as the Chairperson of the Department Faculty Search Committee and as the Faculty Advisor for Security at the IIT Roorkee Saharanpur Campus. He has demonstrated a commitment to mathematical outreach as a local coordinator for the "Initiation into Mathematics 2024" workshop and as a mentor for the Mathematics Training and Talent Search (MTTS) trust. His professional service includes acting as an organizing committee member for the Russia-Japan-India Workshop on mathematical analysis of fracture phenomena.

Invited Talk

On generalized likelihood estimation based on the logarithmic norm relative entropy

Nil Kamal Hazra
Indian Institute of Technology Jodhpur, India

Abstract: Traditional likelihood based methods for parameter estimation get highly affected when the given data is contaminated by outliers even in a small proportion. In this paper, we consider a robust parameter estimation method, namely the minimum logarithmic norm relative entropy (LNRE) estimation procedure, and study different (generalized) sufficiency principles associated with it. We introduce a new two-parameter power-law family of distributions (namely, Mα,β)-family), which is shown to have a fixed number of sufficient statistics, independent of the sample size, with respect to the generalized likelihood function associated with the LNRE. Then, we obtain the generalized minimal sufficient statistic for this family and derive the generalized Rao-Blackwell theorem and the generalized Cramér-Rao lower bound for the minimum LNRE estimation. We also study the minimum LNRE estimators (MLNREEs) for the family of Student's distributions particularly in detail. Our general results reduces to the classical likelihood based results under the exponential family of distributions at specific choices of the tuning parameter α and β. Finally, we present simulation studies followed by a real data analysis, which highlight the practical utility of the MLNREEs for data contaminated by possible outliers.

Dr. Nil Kamal Hazra is currently working as an Associate Professor at IIT Jodhpur. He obtained his Ph.D. degree in Reliability Theory from IISER Kolkata. After completion of his PhD, he joined as a Visiting Scientist at ISI Kolkata. Then, he moved to South Africa to pursue his postdoctoral research career, and he joined as a Claude Leon Postdoctoral Fellow in the Department of Mathematical Statistics at University of Free State, Bloemfontein. Then he started his professional career as an Assistant Professor in the Department of Mathematics at IIITDM Kancheepuram, Chennai. After spending one year at IIITDM Kancheepuram, he moved to IIT Jodhpur where he is currently working.

His current research interest includes Statistical Reliability Theory, Applied Probability, Robust Statistical Inference. He has been appointed as an Associate Editor in leading statistical journals, namely, Opsearch, Communications in Statistics-Theory and Methods, Communications in Statistics-Simulations and Computations, and Communications in Statistics- Case Studies and Data Analysis.

Invited Talk

Fixed Points and Equilibria Beyond Linearity: New Results on Noncompact Hadamard

Monirul Islam (joint work with Adrian Petruşel and Xiaopeng Zhao)
Aligarh Muslim University, Aligarh, India

Abstract : In this paper, we investigate fixed point and equilibrium problems in the geometric framework of Hadamard manifolds, with particular emphasis on noncompact settings. We first establish a coincidence theorem for a class of set-valued mappings defined on noncompact subsets of Hadamard manifolds. As consequences, we derive several new fixed point theorems for families of set-valued maps, which extend and unify a number of existing results in nonlinear and variational analysis. Utilizing these fixed point results, we prove the existence of social equilibrium problems in Hadamard manifolds. Furthermore, we obtain existence results for saddle points, minimax theorems, and Nash equilibria by exploiting the social equilibrium framework. Finally, we introduce and study systems of quasi-variational inequalities on Hadamard manifolds and establish corresponding existence results under suitable assumptions. The results presented herein significantly generalize classical fixed point and equilibrium theorems from linear spaces to noncompact Hadamard manifolds, thereby broadening their applicability in optimization theory, variational analysis, and game theory.

Dr. Monirul Islam is an Assistant Professor in the Department of Mathematics at Aligarh Muslim University (AMU), where he has been a faculty member since January 2020. He completed his entire higher education at AMU, earning his Ph.D. in 2019 with a dissertation on "Generalized Convexity and Nonsmooth Variational Inequalities on Manifolds". His academic excellence was recognized early in his career through the Maulana Azad National Fellowship (MANF), which supported both his Junior and Senior Research periods, and the Merit-Cum Means Scholarship granted by the Government of India.

His primary research expertise lies in Nonlinear Analysis, Equilibrium Problems, and Convex Optimization on Riemannian and Hadamard manifolds. Dr. Islam has established a prolific publication record in high-impact international journals, including Numerical Algorithms, Applicable Analysis, the Journal of Nonlinear and Convex Analysis, Mathematics, and the Journal of Inequalities and Applications. His research often investigates nonsmooth convexity, monotonicity, and iterative algorithms for solving coincidence and fixed-point problems on noncompact manifolds. Beyond traditional research, he has made significant contributions to digital pedagogy by developing a 4-credit MOOC course titled "Metric Spaces" for the SWAYAM platform. Dr. Islam is an active member of the global mathematical community, holding life memberships in the Working Group on Generalized Convexity and the Indian Mathematical Society. He has also held several administrative responsibilities at AMU, currently serving as a Warden for Sir Shah Sulaiman Hall and as the Warden in-charge for sports. His international profile is marked by multiple research visits to Taiwan, including collaborative work at National Sun Yat-sen University, China Medical University Hospital, and Kaohsiung Medical University. Throughout his career, he has presented his research at various prestigious forums, such as the Spring School and Workshop on Variational Analysis and Optimization (VIASM) in Vietnam, the International Workshop on Applied Analysis and Optimization (IWAAO) in Taiwan, the International ISIAM Conference, and the Indo-French Seminar on Recent Developments in Nonlinear Optimization Problems and Applications at Banaras Hindu University.

Invited Talk

Optimization on Manifolds

Akhlad Iqbal
Aligarh Muslim University, Aligarh, Uttar Pradesh, India

Abstract: Optimization on manifolds has emerged as a powerful framework for solving problems with intrinsic geometric constraints arising in mathematics, engineering, and data sciences. In this talk, we present an overview of optimization problems defined on smooth and non-Euclidean manifolds, emphasizing how geometric structures influence

optimality conditions and solution methods. Special attention is given to interval-valued objective functions, where uncertainty and imprecision are naturally incorporated into the optimization process. Using tools from differential geometry and generalized differentiability, we discuss necessary optimality conditions and illustrate how classical optimization concepts extend to manifold settings. The talk aims to provide both theoretical insight and motivation for further research in manifold-based optimization.

Dr. Akhlad Iqbal is an Assistant Professor in the Department of Mathematics at Aligarh Muslim University (AMU), Aligarh, India, where he has been serving since 2015. He earned his Ph.D. in Mathematics from AMU in 2011, with a thesis titled "A Study of the Generalized Convexities on Riemannian Manifolds." He has also received a full CEU fellowship for higher studies in Budapest, Hungary. Over the years, he has taught at reputed institutions including Integral University, BITS Pilani Hyderabad Campus, and the Central University of Punjab before joining AMU.

Dr. Iqbal's research interests lie in Generalized Convexity, Multiobjective Optimization, Variational Inequality Problems, and Optimization on Differentiable and Riemannian Manifolds. He has successfully completed a UGC-funded research project on generalized convexity and Hermite-Hadamard inequalities on Riemannian manifolds and has supervised doctoral research in advanced topics of convexity and interval-valued functions. With extensive teaching experience across undergraduate and postgraduate levels, he has taught a wide range of courses including Algebra, Differential Geometry, Optimization, Probability and Statistics, and Differentiable Manifolds. Proficient in LaTeX, MATLAB, Mathematica, and other computational tools, Dr. Iqbal combines strong theoretical foundations with modern computational approaches in both his research and teaching.

Invited Talk

A nonmonotone descent direction method for nonsmooth multiobjective optimization problems

Jauny
SRM Institute of Science and Technology, Chennai, Tamil Nadu, India

Abstract: For unconstrained smooth multiobjective optimization problems (MOPs), various classical methods (steepest descent, conjugate gradient, Newton, trust-region methods, etc.) with monotone and nonmonotone line searches have been extended from scalar optimization. Over the past several years, researchers have developed methods

for unconstrained nonsmooth MOPs. This paper introduces a new nonmonotone line search algorithm to identify Pareto critical points for a class of unconstrained nonsmooth MOPs. To accomplish this goal, we first present an efficient descent direction method that utilizes ε-subgradients of each objective function to find the descent direction at each iteration. Then, the step length along the descent direction is chosen based on the nonsmooth nonmonotone Armijo condition. Under mild and standard conditions, we prove that every accumulation point of the sequence produced by the proposed method is Pareto critical. Additionally, the effectiveness of the algorithm is validated through implementation in MATLAB and testing on several convex and nonconvex nonsmooth problems, which confirms its practical applicability and robustness.

Dr. Jauny is an Assistant Professor in the Department of Mathematics at SRMIST Chennai, a position he has held since December 2025. He earned his Ph.D. in Applied Mathematics from the Indian Institute of Technology (BHU), Varanasi, in 2022. Prior to his current appointment, he served as a Post-Doctoral Researcher at IIT Bhilai and held faculty positions as an Assistant Professor at GLA University, Mathura, and as a contractual Assistant Professor at NIT Bhopal (MANIT).

His primary research expertise lies in Optimization Techniques and Quasi-equilibrium Problems. Dr. Jauny has published research in notable journals such as Soft Computing and has contributed to book chapters published by CRC Press, specifically focusing on cone methods for uncertain multiobjective optimization problems with minmax robustness. His recent scholarly work includes investigations into iterative methods for projected solutions of quasi-equilibrium problems, with papers submitted to prestigious outlets like the Journal of Global Optimization.

Dr. Jauny is an active participant in the academic community, having presented his findings at several significant forums, including the Indo-French Seminar on Optimization, Variational Analysis & Applications (IFSOVAA) and the International Conference on Nonlinear Applied Analysis and Optimization at IIT (BHU). He also participated in the 8th International Conference on Recent Advances in Science (ICRAS-2024). His professional development includes a research internship at the Indo-French Centre for Applied Mathematics (IFCAM) held at the Indian Institue of Science (IISc), Banglore.

Invited Talk

Reliability analysis of a dynamic system for the general family of inverted exponentiated

Suchandan Kayal (joint work with Kaushik Gupta)
National Institute of Technology Rourkela, Odisha, India

Abstract: Using a general family of inverted exponentiated distributions as a baseline model, we have constructed a number of statistical conclusions on the composite dynamic system in this work. Through a power trend mechanism, component failure in this dynamic system raises the component hazard rate by placing an increased burden on the remaining components. The Bayesian and classical point estimates for the unknown parameters that constitute the composite system are obtained using the Markov chain Monte Carlo and the maximum likelihood methodologies, respectively. To get Bayes estimates for the parameters that are unknown with the squared error as well as generalized entropy loss functions, we have used independent gamma priors in the Bayesian framework. The interval estimates associated with the baseline reliability function are obtained using the Fisher information matrix and the Bayesian technique. A parametric hypothesis test is provided to ascertain whenever the failed components change the hazard rate function. Finally, a simulation study is carried out to examine how the proposed estimate methodologies behave.

Dr. Suchandan Kayal is an Associate Professor in the Department of Mathematics at the National Institute of Technology (NIT) Rourkela, where he has been a faculty member since March 2014. He earned his Ph.D. in Statistics from the Indian Institute of Technology Kharagpur in 2011, focusing on estimating the entropy of exponential and Pareto populations under the supervision of Prof. Somesh Kumar. Before joining NIT Rourkela, he served as an Assistant Professor at BIT Mesra and held a Post-Doctoral Fellowship at IIT Bombay. His research expertise spans Statistical Inference, Information Theory, Reliability Analysis, and Applied Probability. Dr. Kayal has authored over 100 research papers in well-regarded international journals, including IEEE Transactions on Information Theory, Communications in Statistics-Theory and Methods, Metrika, and Journal of Statistical Computation and Simulation. His recent work delves into copula-based extropy measures, stochastic comparisons of finite mixture models, and statistical inference for competing risks data. He has successfully supervised five Ph.D. students and is currently mentoring five others in specialized areas of statistical modelling.

In the editorial and professional realm, Dr. Kayal holds several prestigious positions, including serving as an Associate Editor for Communications in Statistics in the areas of Theory and Methods, Simulation and Computation, and Case Studies. He has also served as a Guest Editor for the Journal of Computational and Applied Mathematics and Axioms. His research has been supported by significant grants from the Science and Engineering Research Board (SERB), covering projects on finite mixture models and stochastic inequalities.

Dr. Kayal is a recipient of the Dr. C. R. Rao Gold Medal Award (2024) and the Young Scientist Award (2012) from the Indian Science Congress Association. He is an active speaker in the global academic community, delivering invited and planetary talks at institutions like IIT Ropar and NIT Sikkim on topics such as extreme order statistics and heterogeneous location-scale models

Invited Talk

Conjugate Gradient Methods for Set Optimization with Finitely Many Objectives

Krishan Kumar (joint work with Debdas Ghosh, Jen-Chih Yao, and Xiaopeng Zhao)
Indian Institute of Technology Kanpur, India

Abstract: Set optimization deals with optimization problems in which the objective value is a set rather than a single numerical quantity, allowing the modelling of complex systems involving multiple criteria, uncertainty, and competing objectives. Such problems naturally arise in areas such as engineering, economics, finance, and decision theory. This work develops nonlinear conjugate gradient methods for solving unconstrained set optimization problems whose objective functions are given by a finite number of continuously differentiable vector-valued functions. Such set optimization problems plays an important role in computing solutions of robust vector optimization problems under finite uncertainty sets. The proposed framework introduces a general conjugate gradient algorithm combined with a Wolfe-type line search strategy, without imposing explicit restrictions on the conjugate parameter. Two important variants, namely Fletcher-Reeves and conjugate descent, are also incorporated using two different choices for conjugate parameter within the same framework. In the algorithm, the direction of movement at each iterate is identified by finding out the descent direction of a vector optimization problem. This vector optimization problem is identified with the help of the concept of partition set at the current iterate. As this vector optimization problem is different at different iterations, the conventional conjugate gradient method for vector optimization cannot be directly extended to solve the set optimization problem under consideration. Theoretical analysis establishes the well-definedness of the proposed algorithms. A Zoutendijk type condition is obtained, ensuring global convergence of the generated sequence even in the absence of convexity of the objective function under mild and practically verifiable assumptions. Numerical examples are presented to demonstrate the performance of the proposed methods. A comparative study with the existing steepest descent approach is conducted,

and it is found that the proposed method commonly outperforms the existing steepest descent method for considered set optimization problems.

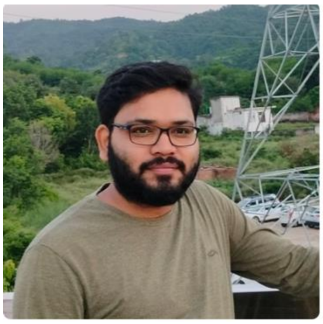
Dr. Krishan Kumar is a Postdoctoral Fellow at the Indian Institute of Technology Kanpur, where he has been working since October 2025 on a research project focused on developing advanced energy systems modeling tools. He earned his Ph.D. in Mathematics from the Indian Institute of Technology (BHU) Varanasi in 2025. His primary research expertise lies in Multiobjective and Set-Valued Optimization, including derivative-free methods, nonmonotone algorithms, and variational analysis with real-world applications. In the professional and editorial realm, Dr. Kumar serves as a reviewer for several prestigious journals, including the Journal of Optimization Theory and Applications, Computational and Applied Mathematics, and Acta Mathematica Scientia.

Invited Talk

Analysis of a manufacturing queueing system using bi-level randomized policy

Nitin Kumar
Indian Institute of Technology Jammu, India

Abstract: In my talk, I will begin with a detailed discussion of a basic queueing model. Then, I will introduce a GI/M/1 queueing model with a randomized policy. To determine the probability distribution of the system content at different epochs, I will perform a steady-state analysis using two well-known methods: the supplementary variable technique and the difference equation approach. Additionally, I will explore various performance measures and conduct a cost analysis of the model. Finally, to validate the analytical results, I will present numerical examples and examine the impact of various factors on the model's performance characteristics.



Dr. Nitin Kumar is an Assistant Professor at the Indian Institute of Technology Jammu, a position he has held since May 2023. He earned his Ph.D. in Applied Probability from IIT Kharagpur in 2021, specializing in the stochastic modeling and analysis of population models subject to catastrophes under the supervision of Prof. U. C. Gupta. His academic foundation is further solidified by an M.Sc. in Mathematics from IIT Kharagpur and a B.Sc. from M.M.H. College, Ghaziabad. Prior to his faculty appointment, he gained significant research experience as a Postdoctoral

Fellow at IIT Kanpur.

His research expertise lies in the fields of Applied Probability, Stochastic Modeling, Queueing Theory, and Statistics. Dr. Kumar has established a strong publication record with research appearing in prestigious journals such as Annals of Operations Research, Methodology and Computing in Applied Probability, Quality Technology & Quantitative Management, and TOP. His work often focuses on the analysis of batch arrival processes and population growth models under various catastrophic influences and killing mechanisms. Beyond his research, he contributes to institutional leadership as the Chairperson of the Departmental Undergraduate Committee at IIT Jammu.

He is an active participant in the global academic community, having presented papers at international venues such as the 29th European Conference on Operational Research in Valencia, Spain. He has also delivered invited talks and series of lectures at high-level workshops, including those focused on the applications of mathematics in machine learning.

Invited Talk

On Constant Positive Linear Dependence Condition in Mathematical Programs with Equilibrium Constraints

Vivek Laha
Banaras Hindu University, Varanasi, India

Abstract: In this talk, we first extend the constant positive linear dependence (CPLD) condition in terms of convexificators given by Rimpi and Lalitha [Constraint qualifications in terms of convexificators for nonsmooth programming problems with mixed constraints. Optimization. 2023;72(8):2019-2038] for non-smooth scalar optimization problems to nonsmooth multiobjective optimization problems with mixed constraints (MOP) which we denote by MOP-CPLD. It also extends the CPLD condition given by Andreani et al. [On the relation between constant positive linear dependence condition and quasi normality constraint qualification. J Optimization Theory Appl. 2005;125(2):473-483] involving continuously differentiable functions. We establish a strong Karush-Kuhn-Tucker (KKT) optimality condition to identify local Pareto efficient solutions under the MOP-CPLD framework. We also introduce a suitable CPLD condition for a non-smooth multi objective optimization problem with equilibrium constraints in terms of convexificators which is denoted by MOPEC-CPLD. We introduce several non-smooth strong Pareto stationary points for the MOPEC which extend the notions of strong Pareto stationary points given by Zhang et al. [Constraint qualifications and proper Pareto optimality conditions for multiobjective problems with

equilibrium constraints. J Optim The ory Appl. 2018; 176:763-782] for continuously differentiable functions. We provide necessary and sufficient optimality conditions to identify a stationary point as a Pareto efficient solution of the MOPEC under the MOPEC-CPLD condition. Further, we introduce Abadie constraint qualifications for MOPEC which is denoted by MOPEC-SOACQ in terms of Clarke generalized derivative and second-order upper directional derivative given by Pales and Zeidan. This notion utilizes second-order ACQ given by Anchal and Lalita [Second-order optimality conditions for locally Lipschitz vector optimization problems. Optimization. 2023;1-20] for multiobjective optimization problems. We derive second-order necessary optimality conditions in both the primal and the dual forms to identify weak Pareto efficient solutions and strict Pareto efficient solutions of order two for MOPEC by utilizing MOPEC-SOACQ. We give some applications of the results in interval-valued multiobjective optimization problems with equilibrium constraints and in portfolio optimization.

Dr. Vivek Laha is an Assistant Professor in the Department of Mathematics, Institute of Science, Banaras Hindu University (BHU), Varanasi, where he has been a faculty member since June 2016. He earned his Ph.D. and M.Sc. in Mathematics from BHU in 2014 and 2009, respectively. His academic career includes serving as an Assistant Professor at the Indian Institute of Technology Patna and holding a prestigious NBHM Postdoctoral Fellowship at BHU. He is currently a Visiting Fellow at the Universitat Autonoma de Barcelona, Spain, working on a joint research project under the IoE scheme.

His primary research interests encompass Multiobjective Optimization, Variational Inequalities, Generalized Convexity, Nonsmooth Analysis, and Mathematical Programs with Vanishing or Equilibrium Constraints. Dr. Laha has published extensively in top-tier journals such as the Journal of Optimization Theory and Applications, Annals of Operations Research, Optimization, and Journal of Industrial and Management Optimization. He has edited the book Optimization, Variational Analysis and Applications published by Springer. To date, he has successfully supervised five Ph.D. scholars in areas ranging from quasi differentiability to interval-valued programming.

In the editorial and professional realm, Dr. Laha serves as a reviewer for Mathematical Reviews and zbMATH and acts as a referee for numerous international journals, including Numerical Algorithms, Opsearch, and Fuzzy Optimization & Decision Making. He is an active member of the Working Group on Generalized Convexity and the International Society on Multiple Criteria Decision Making. Dr. Laha has managed significant research funding, including a UGC-FRPS Start-Up Grant. His international engagement is further evidenced by invited talks and paper presentations at major conferences in Germany, Italy, Japan, Portugal, Taiwan, and Vietnam.

Invited Talk

On predefined-time stable dynamical systems for inverse quasi-variational inequalities

Prashanta Majee (joint work with Sumit Gupta)
Motilal Nehru National Institute of Technology Allahabad, Prayagraj, India

Abstract: This paper is concerned with the inverse quasi-variational inequality problem in finite-dimensional spaces. Two dynamical systems exhibiting predefined-time stability are proposed for solving the considered problem. The proposed methods are characterized by their ability to reach the equilibrium point within a predetermined time, based on tunable parameters. The predefined-time stability of a dynamical system provides the user with more autonomy and control over the convergence speed. The convergence of the proposed methods is established under standard assumptions on the operators and parameters. Finally, the improvement in convergence speed of the proposed methods over some existing methods in the literature is demonstrated through some numerical experiments. Moreover, the dependence of the settling-time of the trajectories of the proposed methods on the tunable parameter is demonstrated.

Dr. **Prashanta Majee** is an Assistant Professor in the Department of Mathematics at the Motilal Nehru National Institute of Technology (MNNIT) Allahabad, where he has been a faculty member since June 2019. He earned his Ph.D. and M.Sc. in Mathematics from the Indian Institute of Technology Kharagpur.

His research expertise lies in Nonlinear Analysis and Optimization, with a specific focus on split feasibility problems, variational inequalities, and fixed-point theory. Dr. Majee has published numerous research papers in well-regarded international journals, including the Mediterranean Journal of Mathematics, Results in Mathematics, Computational and Applied Mathematics, and Numerical Algorithms. His work often explores novel iterative methods and inertial algorithms for solving complex equilibrium and variational inclusion problems. He has successfully supervised a doctoral student on iterative approaches for variational inclusions and has mentored over a dozen postgraduate projects on topics ranging from traffic equilibrium analysis to dynamical systems.

In the editorial and professional realm, Dr. Majee serves as a reviewer for several prestigious platforms, including Mathematical Reviews (AMS), Journal of Inequalities and Applications, and Computational and Applied Mathematics. Dr. Majee is also an active participant in the global academic community, having presented his research at international venues such as the Joint Mathematics Meetings of the American Mathematical Society in San Diego, California.

Parameter-free first-order methods for smooth nonconvex optimization

Naoki Marumo
University of Tokyo, Japan

Abstract: We consider first-order methods for minimizing nonconvex functions whose gradient and Hessian are both Lipschitz continuous. In this setting, many algorithms have been proposed together with oracle complexity bounds, i.e., bounds on the number of gradient evaluations required to reach a target accuracy. In this talk, we present parameter-free algorithms that require no prior knowledge of problem-dependent constants, including Lipschitz constants, while achieving the same complexity bounds. The algorithms adaptively estimate the Lipschitz constants using two technical inequalities: a Jensen-type inequality for gradients and an error bound for the trapezoidal rule.

Invited Talk

Industry Perspectives on Mathematical Optimization in Semiconductor Process Engineering

Vinay Pandey
Deputy Division Head, Semiconductor Laboratory Ministry of Electronics and Information Technology, Government of India, India

Abstract: Semiconductor manufacturing represents one of the most complex and optimization-intensive industrial systems, involving thousands of tightly coupled process steps, nanometer-scale tolerances, and stringent requirements on yield, reliability, and cost. From an industry perspective, this talk discusses how mathematical optimization underpins modern semiconductor process engineering, often being implicitly embedded within process recipes, equipment control strategies, and fab-level decision-making. Key process modules—including lithography, etching, thin-film deposition, chemical–mechanical planarization, and advanced packaging—can be naturally formulated as constrained, multi-objective, and frequently non-convex optimization problems, subject to physical, thermal–mechanical, and equipment-level

constraints. It is highlighted how optimization concepts arise in critical tasks such as overlay and critical-dimension control, defect and yield minimization under uncertainty, reliability-aware process window design, and large-scale scheduling and dispatch in semiconductor fabrication facilities. Emerging challenges associated with technology scaling, data-driven process control, and three-dimensional integration are discussed to illustrate the growing need for robust, real-time, and uncertainty-aware optimization frameworks with provable performance guarantees. The talk aims to bridge the gap between optimization theory and industrial practice, identifying open problems where advances in mathematical optimization can have immediate and transformative impact on next-generation semiconductor manufacturing.

Dr. Vinay Pandey is an accomplished system engineering professional with extensive expertise in control theory, MEMS sensor development, semiconductor packaging, and high-reliability engineering systems. He currently serves as Deputy Division Head and Scientist-Engineer SF at the Semiconductor Laboratory (SCL), Ministry of Electronics and Information Technology, Government of India. With over 15 years of experience spanning India's semiconductor and space sectors, he has led the design and development of MEMS sensors such as pressure sensors and accelerometers, while also overseeing CMOS packaging and reliability programs for space-grade and semiconductor applications. His leadership involves coordinating multidisciplinary teams across mechanical, electrical, materials, and testing domains to deliver robust and mission-critical technologies.

Dr. Pandey earned his Ph.D. in System Engineering (Control Theory) from IIT (BHU), Varanasi, where his research focused on a minimum operator approach to control design for dynamical systems. Earlier in his career at ISRO, he contributed to the mechanical design and integration of PSLV and GSLV payload systems, including structural and thermal analysis of flight hardware. Beyond his professional roles, he has established advanced research facilities, including an Autonomous Vehicle Research Studio, an Inertial Sensor Characterization Laboratory, and a MEMS Characterization and 3D Radiography/CT Laboratory. His work reflects a strong commitment to advancing indigenous technology development in both the space and semiconductor domains.

Invited Talk

Statistical Inference for Copula-Based Regression Models

Ashok Kumar Pathak
Central University of Punjab, Bathinda, India

Abstract: It is well known that regression analysis is one of the most widely used statistical techniques and plays a vital role in studying the dependence between response and predictor variables. Classical regression models have limited applicability in real situations, as these models rely on various assumptions about the dependent variable. Copulas provide a flexible framework for modeling dependence among random variables and have been widely used across fields such as finance, medicine, engineering, agriculture, and geophysics. In this talk, we discuss the relationship between copulas and regression models and propose improved estimation methods for copula based regression models. We study the performance of the proposed estimators using numerical experiments under both specified and misspecified scenarios. We examine various statistical properties, such as unbiasedness, consistency, and asymptotic behavior of the estimators, along with real applications.

Dr. Ashok Kumar Pathak is an Associate Professor in the Department of Mathematics & Statistics at the Central University of Punjab (CUP), Bathinda, a position he has held since 2024. He earned his Ph.D. in Statistics from the Indian Institute of Technology Bombay in 2016, where his doctoral thesis, "On Copulas and Regression Models," was completed under the supervision of Prof. P. Vellaisamy.

His primary research interests encompass Regression Analysis, Copulas and Dependence Modeling, Statistical Inference, and Probability Theory and Stochastic Processes. Dr. Pathak has published over 30 research papers in well-regarded international journals, including Stochastic Analysis and Applications, Journal of Statistical Physics, Journal of Applied Probability, Sankhya B, and Statistics & Probability Letters. His scholarly work frequently explores complex statistical structures such as tempered fractional Poisson processes, bivariate lifetime distributions, and copula-based estimation in multiple linear models. In addition to his core statistical research, he has engaged in high-impact interdisciplinary studies, publishing work on the epidemiological modeling of COVID-19 and the effectiveness of agricultural policies in journals like BMC Infectious Diseases and International Health.

Dr. Pathak has successfully managed significant research funding, including a project under the Mathematical Research Impact Centric Support (MATRICS) scheme from DST SERB and a Research Seed Money grant from CUP Bathinda. His international professional engagement is evidenced by a DST travel grant for the 10th ICSA International Conference in Shanghai, China, and participation in major academic gatherings such as the International Congress of Mathematicians and the International Conference on Statistics and Related Fields at the University of Luxembourg. He has also contributed to several books published by CRC-Apple Academic Press, focusing on distribution theory and simulation modeling. As a dedicated mentor, he has successfully supervised doctoral students in areas such as fractional stochastic processes and copula-based regression.

Invited Talk

Quantum Computing and quantum-classical hybrid systems for Combinatorial Optimization: Opportunities and Challenges

Laxman Saha
Balurghat College, Dakshin Dinajpur, West Bengal, India

Abstract: Combinatorial optimization problem (COP) is an optimization problem that determines the optimal solution from a finite set of solutions. COPs have their roots in various fields such as computer science, software engineering, and applied mathematics. Due to the NP-hardness nature of COP, the complexity of the problem increases rapidly as the size of the feasible solution space increases and it is challenging to find an optimal solution with reasonable time complexity on a classic computer. Quantum computing is as an efficient way to solve COP problems. Quantum annealing (QA) has the potential to significantly improve solution quality and reduce time complexity in solving COPs compared to classical optimization methods. But real-world COPs cannot be directly solved on quantum annealers because of hardware limitations of the existing quantum annealer. Therefore, to overcome this, one should developed methods for reducing the size of COPs to a scale that can be operated in a quantum annealer directly. For example, to solve graph coloring problem, the graph is partitioned into multiple subgraphs through hierarchical techniques and then Quantum Approximation Optimization Algorithm (QAOA) techniques are to be applied to solve coloring problem within the subgraphs. Frequency Assignment Problem (FAP) and finding Optimal Navigating Sets of a network are two important graph theoretic COPs having potential applications in communication networks. Here our main interest are (1) to discuss the opportunities and challenges of quantum computing for solving different graph theoretic COPs such as frequency allocation in networking efficiently, flight scheduling and optimal navigating sets (2) to highlight the importance of quantum-classical hybrid system for solving different COPs such as FAP and finding Optimal navigating sets.

Dr. Laxman Saha is an Associate Professor in the Department of Mathematics at Balurghat College, where he has been a faculty member since July 2010. He earned his Ph.D. and M.Sc. in Mathematics from the Indian Institute of Technology Kharagpur. With over 14 years of teaching experience, he has also served as a guest faculty member at Dakshin Dinajpur University and a teaching assistant at IIT Kharagpur.

His primary research expertise lies in Graph Theory and Combinatorics, specifically focusing on metric dimension, resolving sets, and distance-constrained labeling of graphs. Dr. Saha has a strong publication record with 21 papers in SCI journals and several others in Scopus-indexed outlets. He has successfully managed significant sponsored research projects as a Principal Investigator, including a project on k-level metric bases funded by SERB (DST) and a project on distance-constrained labeling of trees sponsored by the National Board for Higher Mathematics (NBHM). He has also successfully guided five Ph.D. students to completion in these specialized areas.

In the editorial realm, Dr. Saha serves as an Editorial Board member for Mathematics and Computer Science and as a reviewer for the Advances in Science, Technology and Engineering Systems Journal. He has also acted as a guest reviewer for several prestigious SCI journals, including Discussiones Mathematicae Graph Theory, Discrete Applied Mathematics, and the Journal of Combinatorial Optimization. His professional contributions have been recognized with awards such as the "Best Paper Award" from the University of Allahabad and the "Outstanding Paper Award" at the 2nd Regional Science and Technology Congress. Dr. Saha has also traveled internationally to present his work, notably attending the CTW 2012 conference in Germany supported by a DST travel grant.

Invited Talk

Necessary Optimality conditions beyond KKT

Kuntal Som (joint work with Neeraj Bhatt, D. Thirumulanathan and Joydeep Dutta)
Indian Institute of Technology Jodhpur, India

Abstract: In this talk, I will introduce the AKKT conditions and explain how they serve as a necessary condition for optimality even when the well-known constraint qualifications are not satisfied by the constrained optimization problem. Specifically, I consider a simple bilevel program that fails to satisfy the Slater's constraint qualification and show that the AKKT conditions can be used to characterize optimality. I will also introduce the U-condition and explain our work on showing that if any constraint qualification along with AKKT implied KKT, then the constraint qualification implies U-condition. This in some sense shows that U-condition is

possibly the weakest of all conditions where AKKT implies KKT. I will finally describe our work where we attempt to generalize the U-condition for non-smooth settings both in convex and the locally Lipschitz case.

Dr. Kuntal Som is an Assistant Professor in the Department of Mathematics at the Indian Institute of Technology Jodhpur. He earned his Ph.D. in Mathematics from IIT Madras in 2021, where his doctoral thesis focused on the existence, well-posedness, and robustness of set-valued optimization problems. His academic background also includes an M.Sc. in Mathematics from IIT Madras and a B.Sc. (Hons.) in Mathematics from the University of Calcutta. Before joining the faculty at IIT Jodhpur, Dr. Som held prestigious research positions, including serving as a National Postdoctoral Fellow (DST-SERB) and a Postdoctoral Fellow at IIT Kanpur, as well as a Postdoctoral Researcher at IIT Madras.

His primary research expertise lies in the sophisticated domains of Set-valued Optimization, Robust Optimization, and Bilevel Programming. Dr. Som's research interests further extend to Multi-objective Optimization, Semidefinite Programming, and the interdisciplinary fields of Quantum Information and Communication. His work in these areas often addresses the theoretical foundations and stability of optimization problems under uncertainty, contributing to the development of resilient mathematical models for complex decision-making scenarios.

Throughout his burgeoning career, Dr. Som has been actively engaged with the broader mathematical community, building on his extensive postdoctoral experience supported by the Department of Science and Technology (DST-SERB). His transition from high-level postdoctoral research to a faculty position at a premiere institute like IIT Jodhpur underscores his significant contributions to the field of mathematical optimization and his commitment to advanced academic instruction.

Invited Talk

Scalarization and Well-Posedness for Set Optimization Problems Involving General Set Less Relations

Zai-Yun Peng
Yunnan Normal University, China

Abstract: The aim of this paper is to investigate the scalarization and well-posedness for set optimization problems where the solution concept is given by the lower set less relation induced by general sets. First, we propose three kinds of well-posedness for set optimization problems via general sets and study their relationships. Moreover, some sufficient conditions for these kinds of well-posedness for set optimization problems via free-disposal set are obtained under the Hausdorff P-continuity of the objective

mapping of the set optimization problem, rather than the continuity in the sense of Berge. By employing a nonlinear scalarization technique by means of the oriented distance function, corresponding scalar optimization problems are established, and the relationship between solutions of the set optimization problem where the solution concept is given by the lower set less relation induced by co-radiant sets and solutions of the corresponding scalarized problem is also discussed. Furthermore, we also give some characterization of well-posedness for set optimization problem through two scalar optimization problems. Some examples are given to illustrate the main results.

Professor Zai-Yun Peng is a Third-grade Professor and Executive Director of the International Research Center for Mathematical Optimization Theory and Applications at Yunnan Normal University, where he also serves as a Ph.D. and Postdoctoral Research Supervisor. He is a council member of the Management and Decision Science Committee of the Chinese Society of Modern Management and the Mathematical Programming Branch of the Operations Research Society of China. Recognized as a high-level talent at Yunnan Normal University, Professor Peng has previously held several distinguished positions, including “Bayu Scholar” Distinguished Professor of Chongqing Municipality and Vice President of the Operations Research Society of Chongqing. He has also played key academic leadership roles at Chongqing Jiaotong University, serving as Chairman of the Academic Committee of the School of Mathematics and Statistics and leading innovative research teams in optimization theory and applications.

Professor Peng’s research focuses on vector optimization theory and its applications. He has published more than 100 academic papers in leading international journals, including over 80 SCI-indexed articles, with several appearing in top-tier and highly cited venues. He has led more than 20 national and provincial research projects, including grants from the National Natural Science Foundation of China and major postdoctoral funding programs, while also contributing as a key researcher to numerous large-scale projects. His international academic engagement includes visiting scholar positions at the University of British Columbia, The Hong Kong Polytechnic University, The Chinese University of Hong Kong, and the Chinese Academy of Sciences. An active contributor to the academic community, he serves on the editorial boards of several international journals and is Editor-in-Chief of Fixed Point Methods and Optimization.

Oral Presentations

On Erlang Queue with Multiple Arrivals and Its Time-Changed Variant

Rohini Bhagwanrao Pote and Kuldeep Kumar Kataria
Indian Institute of Technology Bhilai, Rajasthan, India

Abstract: We introduce and study a queue with the Erlang service system and whose arrivals are governed by a counting process in which there is a possibility of more than one arrival at any instant. We call it the Erlang queue with multiple arrivals. We derive a system of differential equations for its transient probabilities. Its probability generating function is obtained from which the explicit expressions of its transient probabilities are derived. Also, the probability of zero customers at any instant is obtained. Further, we define the queue length process for Erlang queue with multiple arrivals and obtain a system of differential equations for its mean queue length. We derive the explicit expression for the mean queue length and the second moment of the queue length process. Also, we study a time-changed variant of it by subordinating it with an independent inverse stable subordinator for which we obtain its state probabilities, mean queue length and distribution of busy period.

A Double Inertial Mann Algorithm for Fixed Point and Split Equilibrium Problems with an Application to Depression Classification

Watcharapon Yajai
School of Science, University of Phayao, Thailand

Abstract: The Depression Student dataset is a survey of university students that aggregates demographic, academic, and lifestyle variables with depression-status labels for data-driven analysis and risk prediction. Using the Depression Student dataset, we design novel machine-learning methods that yield more accurate depression-risk screening models. We propose a double inertial Mann algorithm for finding a common solution to a fixed-point problem in real Hilbert space. We apply the obtained main result for the problem of finding a solution of split equilibrium problem. The discussions on the numerical experiments, we use algorithm apply to classify depression dataset among university students. The 95.42% accuracy shows that our algorithm has the highest performance, more than existing algorithms. An application

to mental-health prediction that is reproducible and readily extensible to broader data-driven medical tasks.

Value Appropriation Economic Networks: Does Relational Strength Matter?

Saroj Kumar Pani
Indian Institute of Management Raipur, Chhattisgarh, India

Abstract: Using a dependency based index called nodal power, we investigate how change in structural characteristics and relational content affect profit potential of firms in economic networks. We use formal method of analysis supported by simple simulation to show how relational strength affect a firm's potential to appropriate value from its embedded structure. We also investigate the inter-relationship between network structure, conduct, and performance and show how conduct of constituents influences a firm's profit potential. Our analysis shows that efficiency in maintaining and/or renovation of relationships in economic networks, as well as strong relationships contributes to higher profit potential. Our explorations, we believe, will facilitate further theoretical and empirical research from the embeddedness perspective and help practitioners in managing real world networks such as a firm's value net.

Fuzzy Nonlinear Profit Optimization by Introducing Critical Success Factor Analysis in Quick Service Restaurants(QSR): A Multi-Criteria Supply Chain Approach

Haridas Mondal, Sagnic Naskar and Shariful Alam
Indian Institute of Engineering Science and Technology, Shibpur, India

Abstract: The food and beverage industry, particularly fast-growing supply chains, constantly strives to balance cost efficiency, food quality, service, and customer satisfaction. In the highly competitive quick service restaurant (QSR) sector, effective management is essential for maximizing profitability along with sustainable growth. This study presents a hybrid framework by identifying critical supply chain(SC) risk or success factors(SFs) and integrating the most significant SFs of QSR into a nonlinear QSR optimization model. A fuzzy Multi-Criteria Decision-Making (MCDM) methodology is incorporated to evaluate influential QSR SFs, based on real-life expert reviews, and identifies the most crucial SFs. These factors are subsequently incorporated as decision variables into the nonlinear profit function of the comprehensive profit optimization framework of the QSR SC model. This model analytically establishes concavity through second-order derivative analysis, ensuring a global maximum. A fuzzy extension of the model is demonstrated through the triangular

fuzzy α-cut technique to address real-world demand uncertainty and price sensitivity, which allows the estimation of profit intervals. The model shows that improving food quality and service consistency leads to customer satisfaction, a certain threshold of advertising enhances demand and profitability, while higher pricing reduces demand at a certain level.

Profitable Reverse Chain of Any Dual-Channel Supply Chain with Product Quality Concerns under Dynamic Decision Support System

Sagnic Naskar, Shariful Alam and Arindam Garai
Indian Institute of Engineering Science and Technology, Shibpur, India

Abstract: Many real-life medium and large-scale organizations have shifted to online selling of products within dual-channel supply chain framework, whereas legislation favoring traditional retailers compel managers to often alter the contract mechanisms among centralized decision support systems (DSS) with revenue-sharing and linear quantity discount contract (LQDC) under decentralized DSS. Thus, the major managerial concerns include the optimal choice of DSS while ensuring consistent quality of online products under demand disruptions, a less explored area in dual-channel literature. Moreover, the backdrop of increased environmental awareness causes the emergence of APP-based third-party logistics (ATPL) enterprises, who promote mobile application based direct collection of customers' used items. However, there is a notable gap in investigating the economic independence of reverse chain partner ATPL. Thus, this study delineates one closed-loop dual-channel supply chain, the forward chain of which comprises one manufacturer selling products in both retail and online channels, and the reverse chain involves the ATPL for direct collection and the retailer for in-store collection under dynamic DSS. Results underscore the superiority of LQDC mechanism for significantly higher profitability of chain partners, including ATPL. Curtailing quality maintenance costs in both channels without compromising quality considerably improve the profitability of the proposed model.

An Asymptotic Framework for Comparing Gini Indices using Sequential Procedure under Complex Household Surveys

Shivam, Bhargab Chattopadhyay and Nil Kamal Hazraa
Indian Institute of Technology Jodhpur, Rajasthan, India

Abstract: We develop an asymptotic inference framework for comparing Gini indices

using household-survey data. To evaluate whether there exists a significant difference between the Gini indices of two regions, appropriate hypothesis testing is employed. Inference about inequality difference also proceeds by confidence intervals. For both purposes, we require the precise and reliable estimate of inequality difference. In this paper, we provide the point estimator of the Gini-difference based on complex household survey design that involves stratification, clustering, and sub-stratification. For constructing confidence intervals with narrower bounds or conducting appropriate hypothesis testing with high power requires low variance in estimates. Increasing the cluster size can reduce the variance, but at a higher cost. Hence, the problem is to determine the optimal cluster sizes that ensures a reasonably narrow confidence interval and sufficiently high test power, while minimizing the overall sampling cost. Fixed cluster sizes may not guarantee sufficiently precise confidence intervals or adequate statistical power. To achieve these targets cost-effectively, we propose purely sequential procedure and two-stage procedure that minimizes total sampling cost subject to a pre-specified bound on the variance of the estimator of the Gini-difference. We derive asymptotic optimality properties, including the first-order efficiency property of the proposed sequential procedures without making assumptions about the population distribution. Simulation results indicate that the proposed methods consistently attain the optimality properties across a variety of scenarios. The practical applicability of the approach is further demonstrated through an empirical analysis using data from the National Sample Survey Organization of India.

Goal-Programming Based Multi-Method MCGDM Approach for Tourism State Selection in North-East India within a Cylindrical Neutrosophic Framework

Anita Barman and Shariful Alam
Indian Institute of Engineering Science and Technology, Shibpur, India

Abstract: In this research article, we focus on the development of a novel concept, namely the Cylindrical Neutrosophic Number (CNN), and its application in the field of decision-making under uncertainty. To this end, we introduce Dombi logarithmic aggregation operational laws within the framework of cylindrical neutrosophic numbers and employ these laws to construct a new aggregation operator, referred to as the cylindrical neutrosophic Dombi weighted logarithmic aggregation operator ($C\ NDWL\ A$). Furthermore, a new Multi-Criteria Group Decision-Making (MCGDM) methodology is proposed by integrating the aforementioned operational laws and the $C\ NDWL\ A$ operator within a cylindrical neutrosophic environment.
The proposed MCGDM framework is then effectively applied to the selection of the

most suitable tourist state in North-East India, incorporating Goal Programming (GP) alongside several well-established multi-method decision-making techniques. In this context, the criteria weights are determined using a combination of extensive public survey data and the Criteria Importance Through Intercriteria Correlation (CRITIC-M) method. Sub-sequently, multiple evaluation techniques—namely the Weighted Aggregated Sum Product Assessment (WAS-PAS), Vlse Kriterijumska Optimizacija Kompromisno Resenje (VIKOR), Combinative Distance-Based Assessment (CODAS), and the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS)—are employed to identify the optimal alternative. Finally, comprehensive sensitivity and comparative analyses are conducted to validate the robustness, reliability, and practical applicability of the proposed decision-support framework.

Graph-Theoretic Stochastic Modeling in High-Dimensional Quantitative Finance: A Unified Framework for Systemic Risk and Portfolio Optimization

Shubhayu Brahmachari
Rajiv Gandhi Institute of Petroleum Technology, Jais, Amethi, Uttar Pradesh, India

Abstract: Modern financial markets exhibit complex dependencies that traditional, low-dimensional econometric models fail to capture. This paper introduces a unified Stochastic Graph Neural Network (SGNN) framework, integrating Geometric Deep Learning with Stochastic Optimization to address two pivotal challenges: Systemic Risk Contagion and High-Dimensional Portfolio Optimization.

First, we address systemic risk within interbank liability networks. Classical models, such as the Eisenberg-Noe framework, utilize fixed-point iterations that become computationally intractable under high-dimensional stochastic shock scenarios. We propose a Permutation-Equivariant GNN architecture designed to learn the non-linear clearing functions of financial networks. By training on a wide distribution of graph topologies using Stochastic Gradient Descent (SGD), the model serves as a universal approximator for contagion mechanisms. This topological approach facilitates real-time stress testing of networks with thousands of nodes, successfully identifying "ghost" anomalies—subtle structural vulnerabilities that traditional centrality measures frequently overlook.

Second, we tackle portfolio optimization in high-dimensional regimes where the number of assets exceeds the sample size (\$p \gg n\$). In this setting, standard covariance estimation is ill-posed, resulting in unstable mean-variance optimization. We introduce a variational GNN autoencoder that leverages Stock Relation Graphs—constructed from supply chain linkages and dynamic correlations—to impose a

structural prior on covariance estimation. This method regularizes the high-dimensional problem by learning a latent, low-dimensional representation of market dynamics while preserving essential topological features.

Our framework utilizes Deep Stochastic Optimization to resolve the resulting control problems. By treating GNN parameters as stochastic variables within a Bayesian inference scheme, we quantify epistemic uncertainty—a vital requirement for risk-averse decision-making. We validate our framework using European Interbank Market data and CRSP/Compustat equity data. Results demonstrate that the SGNN approach achieves a 15% reduction in Value-at-Risk (VaR) estimation error compared to classical Monte Carlo methods and significantly outperforms standard shrinkage estimators in out-of-sample Sharpe ratios. This work establishes a rigorous bridge between Deep Learning and Stochastic Financial Calculus, offering a robust toolkit for navigating modern financial uncertainty.

Multi-objective Caputo Fractional Steepest Descent Method With Application in Neural Networks

Barsha Shaw and MAT Ansary
Indian Institute of Technology Jodhpur, Rajasthan, India

Abstract: Fractional calculus, introduced in the 19th century by Joseph Liouville and later advanced through the Riemann–Liouville (R-L) and Caputo formulations, has become an important tool for modelling complex phenomena ([arXiv:2507.07674, 2025]). Its applications span continuum mechanics, elasticity, signal processing, quantum mechanics, bio-engineering, finance, and machine learning ([J. Elast., 107, 105–123, 2012], [Meccanica, 49, 2551–2569, 2014]). The Caputo fractional derivative is adopted in this study because it preserves the fundamental property that the derivative of a constant is zero, unlike the R-L formulation.

Building upon the fractional steepest descent framework already discussed in [Neural Networks, 161, 185–201, 2023] with strong numerical examples. This article introduces the multi-objective adaptive order Caputo fractional gradient descent (MOAOCFGD) algorithm for solving unconstrained multi-objective problems. The proposed method performs equally well for smooth and non-smooth multi-objective optimization problems. Moreover, the proposed method does not require any a priori chosen parameters or ordering information of the objective functions. At every iteration of the proposed method, a subproblem is solved to identify a suitable descent direction toward an optimal solution. This subproblem involves an adaptive-order Caputo fractional gradient for each objective function. An Armijo-type line search is applied to determine a suitable step length. The convergence of this method for the Tikhonov-regularized

solution is justified under mild assumptions. The proposed method is verified using different numerical problems, including neural networks.

Behavioral Mean-Variance Portfolio Selection with Bankruptcy Prohibition

Arindam Maity and Koushik Bera and N. Selvaraju
Indian Institute of Technology Guwahati, Guwahati, India

Abstract: We examine the mean-variance portfolio selection problem with bankruptcy prohibition, incorporating investor behavioral biases through a probability distortion function. In the mean-variance theory, risk is measured by variance, and an investor's objective is to minimize risk corresponding to a given return, or vice versa. Also, in reality, investors make decisions differently regarding gains and losses in the financial market, depending on their individual mindsets. They are generally risk-averse in gaining something and risk-seeking in losing. This dual behavior of investors can be explained by the overestimation of small probabilities and the underestimation of large ones. A probability distortion function can capture this feature of investors' bias. In this setting, the distribution function of the pay-off of a behavioral investor is a transformed distribution of investment payoff, distorted by the distortion function. That is, if X is the actual investment payoff, then the distribution function of behavioral payoff $\tilde{X}$ is $1 - w\big(1 - f_X(x)\big)$, where $F_X(\cdot)$is the distribution function of X. We study the mean-variance problem considering the behavioral payoff ([Math. Financ. Econ., 19, 351379, 2025]). We apply the martingale technique to reduce the dynamic problem into a static optimization problem. We then solve the static problem using the quantile formulation approach to obtain a closed-form optimal solution for the proposed problem. Similar problems are addressed in Bi et al. and Bi and Li ([Eur. J. Oper. Res., 271, 644663, 2018], [Commun. Stat. - Theory Methods, 52, 49044933, 2023]), but they assume specific types of shapes for a function related to the pricing kernel. However, this assumption does not always hold, and we provide a couple of examples to illustrate this explicitly. Our methodology does not depend on the shape of the pricing kernel. Further, we numerically compute the efficient frontier of our model and compare its performance across two deferent distortion functions.

Cost Minimization of Multi-Server Queueing System with Server Vacations using Grasshopper Optimization Algorithm

Gannamaneni Sai Charan and Sudeep Singh Sanga

Sardar Vallabhbhai National Institute of Technology, Surat, India

Abstract: This work investigates a Markovian multi-server queueing system with server vacations. The system comprises multiple servers that provide service, where server availability depends on the number of customers present in the system. In addition, the incorporation of server vacations captures the behaviour of servers that periodically take breaks from rendering service. Using the birth death process framework, the governing equations of the multi-server queueing system are formulated. The recursive method is then applied to these equations to derive the steady-state probability distribution of the continuous-time Markov chain corresponding to the multi-server system. Subsequently, key performance measures are obtained and employed to construct a cost function that depends on the system parameters. This cost function represents the operational cost incurred by the system in terms of server management and customer handling. The primary objective of this study is to minimize the operational cost with respect to the system parameters. The service and server vacation rates are considered to be the decision variables of the minimization problem. To address this optimization problem, a swarm-based metaheuristic, namely the grasshopper optimization algorithm (GOA), is utilized to compute the optimal parameter values. Finally, the practical applicability of the proposed model is demonstrated through a case study of an airport check-in centre.

Symbolic and Machine Learning–Based Cyclicity Detection in Differential Modules

Atrii Roy
Indian Institute of Technology Guwahati, Assam, India

Abstract: Cyclic vectors are a fundamental concept in the theory of linear differential modules, as their existence allows matrix-valued differential systems to be reduced to single higher-order scalar differential equations. Such reductions play a crucial role in differential algebra, differential Galois theory, control systems, and p-adic differential equations. Despite strong theoretical guarantees for cyclicity, practical verification remains computationally expensive due to repeated symbolic differentiation and determinant-based criteria. This work presents a hybrid symbolic and machine learning framework for cyclicity detection in three-dimensional differential modules. The symbolic component is based on Katz's universal cyclic vector construction, together with Pulita's extension to small connections, enabling exact verification of cyclicity through determinant and rank evaluation of the associated Katz matrix. Using this symbolic pipeline as a source of mathematically rigorous ground truth, a dataset of

10,000 labeled differential modules was generated by varying connection matrices, bases, and shift parameters. From each module, structured algebraic features—including matrix invariants, eigenvalue statistics, and basis geometry—were extracted and used to train a supervised Random Forest classifier. Experimental evaluation demonstrates strong predictive performance, achieving an accuracy of 97.05% and an area under the ROC curve (AUC) of 0.9922 on a held-out test set. Misclassifications are primarily concentrated near degenerate cases, reflecting inherent algebraic sensitivity rather than model instability. The results indicate that algebraic cyclicity exhibits learnable structure in low dimensional settings, allowing machine learning to serve as an efficient surrogate for exact symbolic verification during inference. The proposed framework combines mathematical rigor with computational efficiency and is deployed through interactive Streamlit applications for both symbolic verification and real-time cyclicity prediction.

Optimization – Based Modelling and Prediction of Nonlinear Ship Roll Motion Via Hybrid Wavelet-Machine Learning

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SASTRA Deemed University, Thanjavur, India

Abstract: Accurate prediction of nonlinear ship roll motion is essential for assessing stability, safety and performance in realistic ocean environments. Conventional analytical and numerical methods become computationally demanding when strong nonlinearities, parametric uncertainties, and time varying wave excitations are present. In this work, a hybrid wavelet-machine learning framework is proposed to efficiently model and forecast ship roll dynamics. First, the nonlinear roll differential equation is solved using a wavelet operational matrix approach, providing a high-fidelity solution and generating physically consistent roll response data under different wave and damping conditions. These results are compared with other Wavelet algorithms, Runge-Kutta Method (RKM), Artificial Neural Networks (ANN) and Physics-Informed Neural Network (PINN), which serves as a fast surrogate predictor capable of capturing complex nonlinear relationship between roll angle, roll velocity, excitation moment, and future system states. The framework combines the accuracy of physics-based modelling with computational efficiency and generalization capability of data-driven learning. Comparative study demonstrates that the hybrid method significantly reduces computational cost while maintaining high predictive accuracy, making it suitable for real-time prediction, control applications, and design evaluation. The results show that integrating wavelet-based solution with advanced machine learning offers a powerful strategy for analyzing nonlinear ship roll behaviour.

Road Accident Analysis and Prevention Using Autonomous Vehicles with Application for Montrea

Manmeet Singh and Anjali Awasthi
Concordia Institute for Information Systems Engineering, Concordia University, Montreal, Canada

Abstract: Road safety in cities is becoming a bigger concern worldwide. As more people own cars and traffic congestion increases on old roads, the risk of accidents also grows, which severely affects victims and their families. In 2023, data from the Société de l'Assurance Automobile du Québec (SAAQ) reported that 380 people died in traffic accidents in Quebec. A study of road accidents in Montreal between 2012 and 2021 looked at the most dangerous locations, times, and traffic patterns. In this paper, we investigate the role of autonomous vehicles (AVs) vs human-driven vehicles (HDVs) in reducing road accidents in mixed traffic situations. The reaction time of human drivers to road accidents at signalized intersections affects safety and is used to compare the difference between the two situations. Microscopic traffic simulation models (MTMs) namely the Krauss car-following model is developed using SUMO to assess the vehicles performance. Case study 1 assesses the effect of reaction time on human-driven vehicles. The findings show that longer reaction times lead to more collisions. Case study 2 looks at autonomous vehicles and how human-driven vehicles interact in mixed traffic. The simulations tested various levels of AV penetration (0%, 25%, 50%, 75%, and 100%) in mixed traffic and found that more AVs on the road improve safety and reduce the number of accidents.

Research on Clustering Algorithm Based on Penalized Three-Factor Nonnegative Matrix Factorization

Nityansh Pant
Rajiv Gandhi Institute of Petroleum Technology, Jais, Amethi, Uttar Pradesh, India

Abstract: Neural operators have emerged as a principled framework for learning nonlinear solution operators arising in dynamical systems and partial differential equations. However, training such models typically relies on stochastic gradient-based methods whose performance degrades in large-scale settings due to high gradient variance, leading to slow convergence and instability in the learned operator representations. These issues are particularly pronounced when accurate recovery of operator spectral properties is required.

In this work, we investigate whether variance-reduced stochastic optimization methods can improve the efficiency and stability of neural operator training. Formulating neural operator learning as a smooth finite sum nonconvex optimization problem, we adapt stochastic variance-reduced gradient (SVRG) algorithms to operator-valued neural network architectures. We establish convergence guarantees to first-order stationary points under standard smoothness and bounded variance assumptions, demonstrating theoretically that variance reduction yields improved convergence behavior compared to classical stochastic gradient descent.

To assess the impact of optimization accuracy on operator quality, we introduce spectral error measures based on discrepancies between the spectra of learned and reference operators. Using perturbation arguments from operator theory, we relate parameter-space convergence to spectral stability of the learned operators. Systematic numerical experiments on nonlinear and chaotic dynamical systems, including benchmark discrete-time maps and low-dimensional partial differential equations, show that variance-reduced optimization significantly accelerates convergence, reduces gradient variance, and yields more accurate and stable spectral representations than both stochastic gradient descent and adaptive optimization methods.

These results establish variance-reduced stochastic optimization as an effective and theoretically grounded approach for large-scale neural operator training, providing improved optimization efficiency and enhanced operator fidelity in data-driven dynamical systems modeling.

Assessing Bio Energy Schemes in India using SWARA based Multi-criteria Group Decision Making Under Imprecise Environment

Indu Ghosh and Animesh Biswas
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Abstract: Bioenergy is a form of renewable energy that holds significant potential for addressing India's dual challenges of energy security and environmental sustainability. As the world’s third-largest energy consumer with a large agrarian economy and vast biomass resources, India is well-positioned to develop the strategic selection and deployment of bioenergy resources. Due to the complexity of multiple, often conflicting criteria such as environmental impact, cost-effectiveness, and social acceptance, the decision-making process for identifying the most suitable bioenergy scheme requires a robust analytical approach under uncertain environment. To achieve this objective, ZT-spherical fuzzy set (ZT-SFS) is developed, which provides a generalized framework by incorporating both independent and simultaneous representation of membership, abstinence, non-membership, and their reliability. This research proposes new

operational laws under ZT-SFS. Based on this formulation two advanced aggregation operators are proposed using Yu t-norm and t-conorm. Also, this study employs a Multi Criteria Group Decision-Making (MCGDM) method to evaluate and prioritize primary bio energy schemes in India. It collects information through websites, questionnaires, surveys, official statistics, and expert insights. By integrating expert opinions and handling uncertainties inherent in subjective assessments, this study proposes a new decision-making framework that combines the Step-wise Weight Assessment Ratio Analysis (SWARA) for determining criteria weights and the proposed aggregation operator is used for ranking the alternatives. The results confirm that the proposed methodology effectively bridges the gap between theoretical foundations and the practical development of India's bioenergy roadmap, aligning it with renewable energy security and climate goals.

A Profitable Working Vacation Model with Multiple Types of Server Breakdown and Its Application in Smart Temperature Sensor Networks

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Abstract: This investigation deals with the analysis and prediction of the behavior of $M^X/PH/1$ queueing model with working vacation. The queueing server is subjected to multiple types of breakdowns and is repaired in phases. Queue size distribution and other performance indices have been obtained under steady state conditions by employing Matrix-geometric method. An application of the developed model is shown in *Temperature sensors* of a Smart IoT network which in turn helps in conserving energy. In temperature sensors, there are nodes which act as *servers* in queueing terminology. Instead of switching on/off completely, these nodes adjust their activities in such a way that they can work with reduced efficiency. A Working Vacation (WV) behavior allows temperature sensor nodes to continue operating at a reduced service rate instead of completely stop when not in full-service mode or during low service load periods. In working vacation mode, it is found that the node remains partly active and can be switched back to normal mode if changes occur rapidly. It is also the case that the node may fail causing disrupted or slower sensing operations (multiple types of server breakdowns) such as software faults, power issues, or communication errors, etc. Cost optimization has been done via one of the suitable natured inspired algorithms *Particle Swarm Optimization,* which helps the system engineers/decision makers in improving the system in terms of cost and makes the model profitable. Numerical simulation of the application has also been carried out to verify the analytic results. The variation of

performance indices with respect to different parameters is depicted via tables and figures.

Assessing Technical and Cost Efficiency of Municipal Solid Waste Management in India: A Conventional and Inverse DEA Approach

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Abstract: The Urban Local Bodies (ULBs) in India are required by the Solid Waste Management Rules, 2016, and the Swachh Bharat Mission (SBM) guidelines to ensure comprehensive waste collection and processing, as well as the efficient use of public resources. This paper proposes a Data Envelopment Analysis (DEA) model that combines Technical Efficiency (TE) with Cost Efficiency (CE) to assess the capacity of ULBs to produce specified levels of output at the lowest possible cost. Furthermore, an Inverse DEA approach was adopted to estimate the minimum input resources necessary to maintain the current efficiency level, considering both TE and CE. DEA results depict that although several DMUs are technically efficient, CE is generally low, indicating poor input mix and cost management, with Dadra and Nagar Haveli and Daman and Diu emerging as the best overall performers. In addition, results indicate that only a few ULBs, namely Chhattisgarh, Goa, Sikkim, Telangana, Chandigarh, Dadra and Nagar Haveli and Daman and Diu, Delhi, and Puducherry, lie on the efficient frontier, where all have the same TE. However, most of the ULBs are using input inefficiency and thus have the potential to reduce inputs (resources) while continuing to deliver the same level of service. Inverse DEA indicates that maintaining current efficiency levels requires proportional input adjustments, suggesting limited flexibility to proportional input increases without efficiency losses. So, the Inverse DEA model indicates an opportunity to facilitate best practices in this respect for both policy analysis and urban sustainability research and to further advance progress towards SDG 11, SDG 12, and SDG 13.

Smart City Living Performance under Undesirable Outputs: A New Slack DEA Composite Index

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Abstract: Urban living conditions constitute a critical pillar of smart city performance, yet their multidimensional indicators pose significant challenges for composite index construction, particularly when undesirable indicators are present. This study develops a Living Index for 32 Indian Smart Cities using two alternative composite index construction approaches based on a New Slack-Data Envelopment Analysis (NSM) framework. The first approach adopts an indirect modelling strategy, which requires prior transformation of undesirable outputs into adesirable form. The second approach applies a direct NSM formulation, explicitly treating undesirable outputs as indicators to be contracted, thereby preserving their original measurement scale and policy interpretation. The empirical results demonstrate that the direct and indirect NSM models yield near-identical efficiency scores, indicating strong robustness of the proposed Living Index. Efficiency scores range from 0.045 to 1.000, with Pasighat identified as the benchmark city, while considerable heterogeneity is observed across metropolitan, mid-sized, and smaller cities. Several large cities, such as Mumbai, Jaipur, and Jammu, exhibit high living scores, whereas others show substantial scope for improvement. To enhance transparency and credibility, the study conducts ex-post weight diagnostics for both desirable and undesirable indicators. The diagnostics reveal no near-zero weights and balanced weight shares across indicators, mitigating concerns related to extreme weight flexibility commonly associated with DEA-based composite indices. Overall, the proposed framework provides a methodologically robust and policy-relevant tool for benchmarkingurban living performance and supports evidence-based, thoughtful city planning and monitoring.

Dynamic Efficiency Assessment of General Insurance Companies Incorporating Memory Effects through Caputo Aggregation

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Abstract: General insurance companies are essential for economic security, as they manage financial risks and offer stability in the face of uncertainty. In the insurance sector, where financial performance changes over time, it is necessary to evaluate performance using appropriate analytical models. This study analyzes the performance of selected general insurance companies using Caputo aggregation and the New Slack Data Envelopment Analysis Model (NSM). Caputo aggregation is a fractional-order technique that incorporates past observations into present performance using gradually decliningmemory weights. It enables dynamic efficiency evaluation by capturing both short-term and long-term trends. The results demonstrate that fractional alpha values control the influence of past and recent performance in efficiency evaluation. Lower alpha values represent greater historical influence, whereas higher alpha values reflect recent operational changes. After combining memory effects across multiple memory-weight scenarios, the NSM is applied to measure efficiency scores. The analysis includes fifteen decision-making units (DMUs) from the Indian general insurance sector, covering the period from 2017 to 2025. The NSM results show that efficiency scores change only slightly with increasing alpha values, indicating that the selected DMUs maintain stable and robust performance under varying memory conditions. The observed NSM efficiency scores vary from 0.56 to 1 at $\alpha = 0.1$, 0.55 to 1 at $\alpha = 0.5$, and 0.54 to 1 at $\alpha = 1$. Although there is a slight decline in efficiency with higher alpha values, the overall effect remains limited. This implies that variations in memory intensity do not substantially alter the conclusions about relative performance. Overall, the proposed framework strengthens the robustness of benchmarking and leads to more reliable efficiency estimates, thereby supporting informed and sustainable decision-making within insurance companies.

Support Functions and Duality in Groups and Monoids

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Abstract: Convex analysis in the setting of vector spaces has been a significant area of research among mathematicians since a long time due to its applications across disciplines. Lately, the development of a discrete version of the existing convex analysis concepts has gained momentum. Discrete convex sets and functions in finite-

dimensional integer spaces were studied by Adivar and Fang [J. Oper. Res. Soc. China, 6, 189–247, 2018] while Borwein and Giladi [sampler. Math. Program., 168, 11–53, 2018] formalized a canonical theory of convexity for monoids. Li and Mastroeni [J. Convex Anal., 32, 989–1022, 2025] furthered this by obtaining separation theorems and Lagrange type optimality conditions in the discrete setting. Inspired by the preceding developments, in this paper, we introduce the notion of support function of a set in a monoid and explore its properties. To facilitate this, the notions of polar cone and polar set of a set in a monoid are defined. The relationship of the support function of a convex set and the Minkowski functional and indicator function corresponding to its polar is studied. A constrained optimization problem involving support function in its objective function is analysed and Karush–Kuhn–Tucker type optimality conditions and a Wolfe type duality theorem for the same are established.

Some Results on Generalized Derivatives for Interval-Valued Functions and Application in Efficient-Direction Method

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Abstract: This paper studies the fundamental properties (monotonicity, boundedness, continuity and Lipschitz continuity) of directional gH-symmetric derivative for interval-valued functions (IVFs). It is observed that the directional gH-symmetric derivative of gH-Lipschitz continuous IVF is also gH-Lipschitz continuous. Further, it is shown that gH-Gâteaux differentiability implies directional gH-symmetric differentiability, while the converse of this result is not true. With the help of gH-Gâteaux differentiability, we prove the mean value theorem for IVF. To find the optimal solutions of IOP, an efficient-direction method by using gH-Gâteaux derivative is proposed. The entire study is illustrated by suitable examples.

Optimization of raceway parameters in iron making Blast Furnace for maximizing the Pulverized Coal Injection (PCI) rate

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Abstract: This paper presents an optimization-based methodology to predict the maximum feasible pulverized coal injection (PCI) rate in blast furnace operation. The approach integrates a first-principles raceway model with statistical modelling and constrained optimization to determine PCI limits under specified operating conditions,

thereby providing a systematic framework for PCI maximization in practice. Raceway behaviour is first simulated using a fundamental one-dimensional model whose ordinary differential equations are solved with a fourth-order Runge–Kutta algorithm implemented in C++. A factorial design of carefully selected key operating variables is employed to generate a structured data set that spans the relevant operating window, from which a linear PCI-rate model with good interpolation characteristics is developed and statistically validated. This linear model is then used as the objective function in an optimization framework that maximizes PCI by varying controllable operating parameters within prescribed technological and operational bounds, ensuring both feasibility and robustness of the recommended settings.
To estimate the maximum permissible coal injection rate for a given set of blast conditions, a constrained optimization scheme based on the Luus–Jaakola technique is applied specifically in the raceway zone, where combustion and gas–solid interactions are most critical. A large synthetic data set is generated within practical operating ranges using MATLAB, and a linear objective function is constructed from these data for use in the iterative optimization routine. The methodology is validated using operating data from two major Indian steel plants, which are shown to be operating below the optimized PCI levels suggested by the model, indicating substantial untapped PCI potential. The case studies demonstrate that the predictions are reasonably accurate and that the proposed method can effectively guide the systematic and safe increase of PCI rates toward their theoretical limits while satisfying key raceway stability and overall process constraints.

Mitigating Spurious Correlations in Deep Learning with TensorFlow-based Distributionally Robust Optimization

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Abstract: Deep learning models trained with standard Empirical Risk Minimization (ERM) often achieve high average accuracy but fail on underrepresented subpopulations by exploiting spurious correlations. These correlations—such as background and label co-occurrence—can lead to poor generalization when the data distribution shifts, especially for minority groups. This critical failure undermines fairness, robustness, and trust in real-world AI systems. To address this, we propose and implement a Group Distributionally Robust Optimization (Group DRO) framework in TensorFlow that explicitly mitigates performance disparities across predefined subgroups. Group DRO reformulates the training objective as a minimax problem, where the goal is to minimize the worst-case loss over all groups. This naturally fits into the broader class of stochastic optimization under distributional uncertainty, as training is performed using stochastic gradient updates while accounting for worst group risk. Our key technical contributions include (1) an end-to-end training pipeline using ResNet50 on the Waterbirds benchmark, a canonical dataset for evaluating spurious correlation mitigation, and (2) a detailed empirical study of how L2 regularization and early stopping interact with overparameterized models under the Group DRO objective. We show that these components are essential for achieving stable convergence and improving worst-group accuracy. Our results are expected to demonstrate substantial improvements in robustness and fairness over ERM baselines, particularly in settings with subpopulation imbalance. This work bridges deep learning with robust optimization theory, offering practical insights into building equitable and resilient neural networks. Our findings have direct applications in fairness-aware model training and contribute to the broader agenda of trustworthy machine learning under data uncertainty.

A Globally and Superlinearly Convergent Modified SQP-Filter Method for Multiobjective Constrained Optimization Problem

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Abstract: In this work, we propose a modified filter-based sequential quadratic programming (SQP) method for solving nonlinear multiobjective constrained optimization problems. The proposed approach extends the single-objective SQP-filter framework to the multiobjective SQP setting. At each iteration, a quadratic programming subproblem is solved to compute a common feasible descent direction for all objective functions. The Hessian matrices are updated using a modified BFGS scheme that preserves positive definiteness. A multiobjective filter mechanism is incorporated to determine the acceptance of trial iterations without a merit function. Under the Mangasarian–Fromovitz constraint qualification and standard regularity assumptions, the generated sequence is shown to converge to a Pareto critical point. Furthermore, global convergence of the algorithm is established, and superlinear convergence is proved in a neighborhood of a Pareto-optimal solution.

Optimal policy of an Energy-Aware Single-Server Queue with Correlated Arrivals using Markovian Arrival Process

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Abstract: This paper studies an energy-aware single-server queueing system where the server switches to a low-power or off state based on the queue length with service resuming through a turn-off and setup mechanism; see Maccio and Down [Perform. Eval., 90, 36–52, 2015] for details about this scheduling mechanism. Arrivals to this infinite-buffer queueing system are governed by a Markovian Arrival Process (MAP), which allows the modeling of correlated and bursty traffic; see Lucantoni et al. [Adv. Appl. Probab., 22, 676–705, 1990] for details about MAP. To examine the effect of correlation, multiple MAPs with identical mean stationary arrival rate but different correlation structures are considered. The system is modeled as a level-dependent Markov process, and the associated infinitesimal generator for this quasi birth and death (QBD) process is constructed. The stationary distribution is obtained using the characteristic roots associated with the corresponding vector-difference equations obtained from the infinitesimal-generator matrix which exhibits a repetitive block tri-diagonal structure beyond a queue-length threshold. Using the stationary probabilities, performance measures such as the mean queue length, mean waiting time, server utilization, and total expected energy consumption are derived. An optimization framework is developed to determine the optimal queue-length threshold and turn-off rate that minimize a long-run expected cost function incorporating both delay and energy expenditure. Extensive numerical computations are performed to study the impact of arrival correlation on the optimal control parameters and overall system performance. These results provide useful insights into how different correlation structures influence the optimal threshold, turn-off rate, and energy-related measures, even when the mean stationary arrival rate is fixed. These findings emphasize the importance of studying the effect of correlated arrival process in the optimization and design of an energy-aware queuing system.

Anti-Jamming Strategy Selection in Defence Communication Networks using Fuzzy Graph MCDM Model

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Abstract: Selecting an optimal anti-jamming (A-J) strategy in defence communication networks is a complex decision problem, as networks must maintain connectivity, reliability, and operational continuity under hostile and dynamic interference conditions. This study proposes a novel multi-criteria decision-making (MCDM) framework that integrates fuzzy graph (FG) modelling with the technique for order preference by similarity to an ideal solution (TOPSIS) to evaluate and rank alternative A-J configurations. The communication network is represented as a FG, where nodes correspond to tactical communication units and edges denote wireless links characterized by uncertain and time-varying interference levels. Key performance attributes, including interference resistance, signal robustness, transmission efficiency, responsiveness, and operational security are considered as evaluation criteria. The TOPSIS method is employed to rank candidate strategies based on their relative closeness to an ideal interference-resilient state. The FG representation effectively captures link uncertainty and dynamic network behaviour, while the MCDM framework provides a systematic, transparent, and computationally efficient approach for comparative assessment. The proposed model offers a practical decision-support tool for enhancing the survivability and reliability of defence communication networks (DCN) under adversarial jamming and can be extended to other resilient wireless communication planning problems.

Interval Estimation of the Ratio of Scale Parameters for Two Shifted Exponential Populations under Common Location Set-up

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Abstract: Under the exponential model, the ratio of scale parameters corresponds to the hazard ratio, a key measure for comparing relative risk or reliability across populations. Motivated by this concept, we explore the problems of interval estimation for the ratio of scale parameters in two exponential populations that share a common location parameter. We develop and evaluate several techniques for estimating confidence intervals, including asymptotic-like confidence intervals, the method of variance estimate recovery interval, and computational approaches such as the parametric bootstrap-p and bootstrap-t methods. We also construct the highest posterior density (HPD) interval using the Markov chain Monte Carlo method, along with intervals based on the generalized pivot variable technique. To assess the performance of these confidence intervals, we conduct a comprehensive simulation study. It is noted that the HPD interval performs better than others in both coverage probability and average length examples.

Convergence Guarantees for First-Order Methods via Lyapunov Analysis in Composite Strong–Weak Convex Optimization

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Abstract: Nesterov's accelerated gradient (NAG) method extends the classical gradient descent algorithm by improving the convergence rate from $O\left(\frac{1}{t}\right)$ to $O\left(\frac{1}{t^2}\right)$ in convex optimization. In this work, we study the proximal gradient framework for additively separable composite objectives consisting of smooth and non-smooth terms. We show that the Nesterov accelerated proximal gradient method (NAPGα) achieves a convergence rate of $O\left(\frac{1}{t^2}\right)$ for strong-weak convex functions when $\alpha > 3$. A Lyapunov-based analysis is developed to establish the fast convergence of the composite gradient operator in the setting where the smooth component is strongly convex and the non-smooth component is weakly convex. Furthermore, we prove the equivalence between the Nesterov accelerated proximal gradient method and the Ravine accelerated proximal gradient scheme.

Proper Efficiency and Duality for Multiobjective Semi-Infinite Variational Problem Involving Caputo-Fabrizio Fractional Derivative with Applications

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Abstract: In this paper, a multiobjective semi-infinite variational problem is introduced in which the Caputo-Fabrizio (CF) fractional derivative is used instead of the ordinary derivative and involves an infinite index set for the inequality constraints. The concept of proper efficiency (in Geoffrion's sense) is introduced for the considered problem, and optimality conditions and duality results are established under convexity and strict con vexity assumptions. The Wolfe and Mond-Weir type duals are formulated and duality theorems are derived to characterize the relationship between efficient solutions of the pri mal and dual problems. Some non-trivial numerical examples emphasize the

established theoretical results. Furthermore, a multiobjective case study is presented to illustrate the practical applicability of theoretical findings.

Approximate Mixed-Type Duality for Semi-Infinite Programs having Equilibrium Constraints

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Abstract: A mathematical program with infinite constraints is known as a semi-infinite problem. Extensive research is being conducted in this direction, not only due to its remarkable structural features but also because of its various applications in engineering, production, marketing, finance, and management. In this talk, I will explore the optimality and duality aspects of multiobjective semi-infinite programming problems under equilibrium constraints. I will discuss the approximate sufficient optimality criteria for semi-infinite programs with equilibrium constraints using approximate M stationary points in terms of Clarke subdifferential, along with approximate duality results for mixed-type dual problems under the generalized convexity assumptions.

A Novel approach to solve a Fuzzy-Chance Constrained Mean–CDaR–CVaR Portfolio Model under Type-2 Uncertainty

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Abstract: This study proposes a novel fuzzy portfolio optimization framework that integrates type-2 extension of fuzzy-chance constraints and two coherent risk measures Conditional Value-at-Risk (CVaR) and Conditional Drawdown-at-Risk (CDaR), that are evaluated using historical data. A Weighted Average Price (WAP)-based modification of the Amihud's Price Impact measure is introduced and utilized to capture illiquidity of the portfolio. The asset returns and illiquidity are captured as Trigonometric Interval Type-2 Fuzzy Numbers (Tg-IT2FNs) to define objective function. Tg-IT2F returns are further used to extend the chance constraints into type-2 fuzzy environment. A new hybrid methodology has been developed to solve the proposed CVaR-CDaR infused fuzzy-chance-constrained model. The methodology consists determinizing the model, and employing Interactive Weighted Tchebycheff

(IWT) method. To transform the fuzzy objective functions, we are using ranking method for Tg-IT2FNs. The fuzzy chance-constraints are determinized using a three step method; (i) α-cut extraction for Tg-IT2F returns, (ii) handling probabilistic confidence, and (iii) applying acceptability index. The IWT method has been introduced to obtain a solution of the resulting deterministic multi-objective portfolio optimization problem. A numerical example comprising 12 assets is solved, to demonstrate the applicability of the proposed framework, under various investor preference. The numerical results are analyzed and compared with weighted sum method, one of the distinguished methods to solve a multi-objective optimization problem. The comparison highlights the effectiveness of the developed model and approach in constructing a liquid and risk-efficient portfolio.

New Estimates of Post-Quantum Hermite–Hadamard-Type Inequalities for Strongly Convex Functions

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Abstract: The objective of this paper is to explore a novel version of the (p,q)-Hermite–Hadamard inequality for strongly convex functions in the context of post-quantum calculus. Several corresponding estimates for the (p,q)-midpoint and (p,q)-trapezoidal inequalities are also derived for particular classes of (p,q)-differentiable functions by employing left and right (p,q)-derivatives. The proposed inequalities serve as generalizations of previously obtained results. To illustrate the validity and significance of our findings, we provide concrete examples for specific classes of (p,q)-functions.

Multi-Objective Portfolio Rebalancing Framework with Transaction Costs using Interval Optimization

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Abstract: Portfolio rebalancing plays a vital role in dynamic investment decision-making, especially under market uncertainty and the presence of transaction costs. This paper proposes a multi-objective portfolio rebalancing framework with transaction costs using interval optimization, where key parameters such as expected returns, risks, and transaction costs are modeled as interval-valued variables to capture market volatility. The proposed model simultaneously maximizes portfolio return and

minimizes portfolio risk subject to practical constraints, including budget constraints, transaction costs constraints, and portfolio feasibility constraints; see [Math. Oper. Res., 15, 676–713, 1990] for details. The resulting formulation leads to an interval-based multiobjective optimization problem, which is converted into deterministic equivalent models using established interval optimization techniques; see [Opsearch, 52, 827–860, 2015] for details. To obtain efficient trade-off solutions, multi-objective solution approaches such as the weighted sum method, fuzzy programming approach, and genetic algorithms are employed. These methods generate Pareto-optimal portfolios that reflect different investor risk-return preferences under uncertainty. A numerical example involving 10-20 selected stocks from the NIFTY 50 index is presented to demonstrate the applicability and effectiveness of the proposed frame-work. The numerical results indicate that the interval-based multi-objective model provides a better optimal portfolio rebalancing strategies in order to get desired return.

Proximal Gradient Method for Multiobjective Optimization Problems of Interval-Valued Maps

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Abstract: In this paper, we propose a new framework for solving proximal gradient method of interval valued maps for unconstrained non gH-differentiable multiobjective optimization problems with the objective function being the sum of a proper lower gH-semicontinuous convex function and a gH-continuously differentiable function. We have shown under appropriate assumptions that each accumulation point of the sequence generated by the algorithm is Pareto stationary. Further, when gH-convexity is imposed on the smooth component of the objective function, the convergence of the generated iterative sequence is shown to converge to a weak Pareto optimal point. Meanwhile, the convergence rate of the proposed method is analyzed under different assumptions on the smooth component of the objective function. In particular, the convergence rate is $O\left(\frac{1}{\sqrt{k}}\right)$ when the smooth component is nonconvex, $O\left(\frac{1}{k}\right)$ when it is convex, and $O(r^k)$ for some $r \in (0,1)$ when it is strongly convex, where k denotes the number of iterations.

Quantum Multi-Omics Feature Fusion for Pancreatic Cancer Subtyping using QUBO Optimization

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Abstract: Pancreatic ductal adenocarcinoma (PAAD) is among the most aggressive malignancies, with a five-year survival rate of fewer than 12%. Identifying clinically significant subgroups, such as Classical and Basal-like, is critical for better treatment decisions. However, integrating multi-omics data remains difficult due to its high dimensionality and intricate interactions between genetic characteristics at distinct molecular layers. In this article, we present a quantum inspired strategy for integrating multi-omics features with the goal of improving pancreatic cancer subtyping. The joint feature selection issue spanning three omics layers-gene expression (RNA-seq), DNA methylation, and copy number variation (CNV)-is expressed as a Quadratic Unconstrained Binary Optimisation (QUBO). The aim function includes phrases for reducing redundancy across each omics layer, ensuring consistency across shared genes, and choosing features with greater variability. Additional interaction terms are provided to facilitate coordinated data selection across many modalities. The optimisation is carried out via simulated annealing, which is compatible with quantum annealing frameworks such as D-Wave systems. The approach was tested against multi-omics data from 184 PAAD patients received from TCGA. 85 informative features were chosen from a total of 120 features, resulting in a 29% reduction in dimensionality. The selected characteristics have an Adjusted Rand Index (ARI) of 1.0 for subtype classification using K-means clustering. The proposed framework performed comparably or marginally better than a conventional variance-based feature selection method. These results demonstrate that quantum-inspired optimisation may be a useful method for precision oncology's integration of several omics.

A Comprehensive Survey on Quantum Support Vector Machine Algorithms for Large- Scale Optimization Problems

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Abstract: Quantum computing offers a novel approach to computation by utilizing quantum mechanical principles. Quantum Machine Learning (QML) seeks to integrate quantum computation with classical learning models to achieve potential speedups and

enhanced optimization capabilities. Among QML techniques, Quantum Support Vector Machines represent a direct quantum analogue of classical SVMs, designed to address optimization challenges inherent in large-scale learning tasks.
In Large-scale optimization problems are at the heart of modern computing. They show up everywhere—from scientific simulations and engineering design to financial analysis and national-level decision-making. Support Vector Machines (SVMs) have long been a popular choice for tackling classification and regression tasks because they're built on solid theory and tend to generalize well. When datasets get huge and dimensions skyrocket, traditional SVMs start to struggle. The bottlenecks come from two places: the heavy workload of kernel calculations and the tough quadratic programming needed to solve them. Together, these make scaling SVMs to enormous problems a serious challenge.
The survey explores how QSVM methods can help tackle real-world problems, such as predicting bitcoin prices. Because cryptocurrency markets generate huge amounts of complex and highly volatile data, QSVMs may be better at finding hidden patterns and trends than traditional approaches. This makes them promising tools for tasks like risk assessment, analyzing market behavior, and solving large-scale optimization problems. In the other words the overall aim of the paper is to provide researchers and practitioners with a clear and practical resource for applying QML to new areas in computing and finance.

Fast Invariant Optimizers for Large Scale Linear Combinations from an SPD Matrix Cone

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Abstract: We consider the optimal linear mixing problem of n × n symmetric positive definite (SPD) matrices chosen randomly from the SPD cone in dimension $\frac{n(n+1)}{2}$. Define $S^n := \{A \in R^{n\times n} : A^\top = A\}$; $S^n_+ := \{A \in S^n : X^\top AX \geq 0$ for all $x \in R^n\}$; and $S^n_{++} := \{A \in S^n : X^\top AX > 0$ for all $x \in R^n\{0\}\}$, (the set of SPD matrices). It is known that S^n is a vector subspace of $R^{n\times n}$ and dim $(S^n) = \frac{n(n+1)}{2}$. Furthermore, S^n_{++} is a full-dimensional open convex cone within S^n. Consider the ideal linear combination of N i.i.d. random samples from S^n_{++} with scalar multiples $\omega, i = 1, 2, \dots, N$, with sufficiently large N (≥ 100) and moderate n (≤ 10). Here, ideal combination is usually determined by optimizing any one of the invariants (often

the convex trace, and the log-concave determinant functions) of the output matrix (which is still SPD) subject to linear constraints in ω_i in dimension N. Often for the specifications on (N, n), the speed of computation can suffer—despite working with convex functions in a convex space—from faraway initializers. We propose using eigenvalue based scalar surrogates—derived from extremal eigenvalues of each SPD matrix—to create an extremely cheap ($O(n)$ time), high-quality initializer. The surrogate algorithm works by identifying a small pool of eigenvalue-vertices (EV) that provably upper-bounds key SPD invariants (spectral, trace, determinant). The full optimization then involves screening these candidates (one Cholesky operation per candidate, and refining the best with a reduced active-set Newton or a low-dimensional dual. The surrogate functions are shown to have provable bounds arising from the Weyl Triangular inequality for Hermitian matrices (or from the Rayleigh quotient). We show that a Weyl class of such surrogate initializers exists based on the chosen invariant to be optimized in S^n_{++}.
Beyond the theoretical interest, SPD matrix cone problems have immediate applications in disease/crisis detection (time-series mixing), multi-sensor fusion in robotics and terrain mapping (Covariance intersection), outlier detection in AI/ML (Mahalanobis distance), Curvature learning in ManifoldNet (SPD Hessians) and multi-fluid interaction (isotropic tensors). We provide real-time examples from some of the aforementioned fields to demonstrate the efficacy of the proposed computational method. In all cases, the near-optimal weight combinations were found at least 20 % quicker than optimizers without surrogates for such problems.

UMP Tests Based on Sufficient Statistic Associated with Generalized Likelihood Function

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Abstract: Testing statistical hypothesis is one of the common methods used for parametric statistical inference. The monotone likelihood ratio (MLR) property plays a crucial role in constructing uniformly most powerful tests for composite hypotheses. Exponential family is one of the important family as it contains many distributions and also satisfies MLR property. However it does not include some useful distributions like Student's t-distribution. Also, the family of Student's t-distribution do not satisfy the MLR property with respect to the usual likelihood function which results in non-existence of uniformly most powerful (UMP) tests for testing composite hypotheses. In this talk, we introduce a notion of monotone likelihood ratio for a family of probability distribution with respect to some generalized likelihood function. This notion helps in

constructing UMP and uniformly most powerful unbiased (UMPU) tests for families lying outside the exponential family. In particular, we consider one parameter $\beta^{(\alpha)}$ family (contains Student's t-distribution) and discuss the structures of UMP and UMPU tests.

Duality Results for Quasidifferentiable Mathematical Programs with Equilibrium Constraints

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Abstract: The aim of this article is to study a class of nonsmooth mathematical programs with equilibrium constraints (MPECs) and their corresponding dual formulations. Using the framework of quasidifferential calculus, we construct Wolfe-type and Mond–Weir-type dual problems for the considered nonsmooth MPECs. Under appropriate assumptions of quasidifferential invexity with respect to convex compact sets, we establish weak and strong duality results for this class of optimization problems with equilibrium constraints. Several illustrative examples are presented to demonstrate the applicability of the proposed theoretical results. In addition, a comparative discussion is provided to emphasize the advantages of quasidifferential calculus over other generalized differential approaches in the analysis of nonsmooth MPECs.

A Dual Based Neural Network Model for Mathematical Programs having Vanishing Constraints with Applications

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Abstract: In this paper, we study a mathematical programming problem with vanishing constraints (MPVC) and present a neural network model that employs smoothing and regularization techniques. Owing to the existence of critical kinks in the feasible set and the nonsmooth nature of the standard Karush-Kuhn-Tucker (KKT) conditions with respect to the multipliers in (MPVC), we reformulate the (MPVC) problem as a smooth nonlinear programming problem (SNLP(r)), thereby addressing the shortcomings inherent in the original (MPVC) formulation. Subsequently, the optimal solution of the transformed nonlinear problem is approximated using a dual-based neural network model. Theoretical analysis demonstrates that the equilibrium of the network is asymptotically stable and converges to the optimal solution of the problem (MPVC).

Simulation results further support the theoretical findings and confirm the computational efficiency of the proposed model.

Variable-Metric Newton-Like Dynamics for Monotone Inclusions Via Warped Yosida Approximation

Vishal Goyal and Pankaj Gautam
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Abstract: In this paper, we investigate the asymptotic properties of trajectories of a second-order variable-metric Newton-like dynamical system incorporating Tikhonov regularization to solve a monotone inclusion problem. The analysis relies on the warped Yosida approximation of a maximal monotone operator, combined with an appropriate tuning of the regularization parameter. We prove existence and uniqueness of solutions, establish fast convergence rates for the velocity and the warped Yosida regularization term toward zero, and show that the trajectories generated by the dynamical system converge weakly to a solution of the inclusion problem.

Optimizing a Multi-Objective IoT-Driven Closed Loop Supply Chain Network Design using Epsilon-Constraint Pareto Analysis

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Abstract: Supply chain network design is one of the most important issues in today's competitive environment. These networks face unprecedented challenges including supply chain disruptions, demand volatility, transportation bottlenecks, and environmental sustainability concerns. This paper presents a multi-objective, IoT-enabled closed-loop supply chain network design incorporating suppliers, manufacturers, distribution/collection centres, customers, and recycling facilities. The proposed model simultaneously optimizes two conflicting objectives: minimization of total supply chain costs and minimization of environmental impacts. To efficiently address the resulting multi-objective optimization problem, the ε-constraint method–one of the most widely used exact solution approaches–is employed to generate Pareto-optimal solutions. Scalability analysis of the proposed model reveals a critical inflection point at 28 clients, beyond which decentralized strategies become mandatory to maintain feasibility and carbon efficiency. By scaling the network under varying demand patterns, a strategic 'elbow' was identified at the 50-client mark. The system's resilience was evaluated through a rigorous stress test involving randomized demand perturbations in 10% increments. This analysis uncovered a definitive feasibility boundary at a 40% demand surge, marking the point of systemic failure. Beyond this threshold, the fixed capacity of the three-factory infrastructure becomes a critical bottleneck, rendering it unable to reconcile market requirements with the established constraints. This mathematical boundary serves as a "fail-safe" point for strategic planning, highlighting that while the model is resilient to moderate fluctuations, long-term growth requires physical expansion of the manufacturing base. Consequently, this research indicates that managers should maintain operational buffer to hedge against seasonal volatility and supply chain shocks for smart, circular ecosystems.

Proximal-Type Algorithms for ϕ-Best Proximity Points in Banach Spaces

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Abstract: In this talk, the existence and convergence ϕ-best proximity points in Banach spaces are studied via generalized projection operators. Shrinking projection algorithms are developed to approximate common ϕ-best proximity points for nonextensive-type non-self mappings, and their applications in Hilbert spaces are presented. These results extend the best proximity point theory and provide effective methods for solving nonlinear problems for which classical fixed-point approaches are not applicable.

Robust Trajectory Optimization and Autonomous Mission Execution of a Flying Wing UAV in GPS-Denied Environments

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Abstract: Autonomous trajectory design and mission execution in GPS-denied environments pose significant constrained optimization challenges in aerospace systems. This work presents a mathematical optimization framework for guidance, control, and resource management of a semi-stealth flying-wing unmanned aerial vehicle (UAV) operating under navigation uncertainty and communication constraints. The mission planning problem is formulated as a constrained nonlinear optimization problem, where the objective function minimizes a weighted combination of path length, energy consumption and risk exposure, subject to aerodynamic limits, actuator constraints and environmental disturbances such as wind and signal denial. A hybrid

optimization strategy combining heuristic graph-based global planning (A*) with real-time local re-optimization is employed to ensure feasibility and robustness. Under GPS-denied conditions, state estimation uncertainty is incorporated into the trajectory generation process using robust optimization principles, ensuring bounded navigation error propagation.
A hierarchical decision framework further optimizes mission execution by dynamically allocating battery resources, triggering fail-safe modes based on confidence metrics and performing local obstacle avoidance through constrained predictive re-planning. Simulation results demonstrate improved trajectory stability, reduced deviation under spoofing scenarios and enhanced mission reliability compared to non-optimized baseline approaches.
The proposed framework highlights the integration of robust and constrained optimization techniques into UAV guidance and control systems, contributing to aerospace and defense optimization research aligned with national mission objectives.

FISTA-Type Davis–Yin Algorithm for Nonconvex Optimization

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Abstract: In this work, we study a nonconvex and nonsmooth optimization problem involving the sum of three functions using Davis–Yin splitting methods. We present both the Davis–Yin algorithm and a FISTA-type Davis–Yin algorithm, and construct the corresponding Davis–Yin envelope to facilitate convergence analysis. Using this framework, we establish convergence results and residual convergence rates. Finally, a numerical example is provided to compare the residual convergence behavior of the Davis–Yin, FISTA-type Davis–Yin, and Extrapolated Davis–Yin algorithms.

Interval-Valued Optimization Problems for Strongly LU-ε-Invex and Strongly LU-ε-Preinvex Functions

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Abstract: In this paper, we introduce and explore the concepts of strongly LU-ε preinvex (SLUεP), pseudo strongly LU-ε-preinvex (PSLUεP) and strongly LU-ε invex (SLUεI) functions. To illustrate and validate these definitions, we provide several non-trivial examples. Additionally, we extend the idea of strongly-G invex sets to the context of interval-valued functions. The epigraph of a SLUεP function is derived, and we establish a clear relationship between SLUεP and PSLUεP functions. A key contribution of this work is the identification of a significant connection between weakly-strongly ε-invex functions and SLUεP functions. As an application, we consider a nonlinear programming problem involving SLUεP functions. Under certain conditions, we prove that a local minimum of the problem is also a global minimum. Moreover, the sufficiency of Karush-Kuhn-Tucker (KKT) optimality conditions by considering the objective and constraint functions are SLUεI and SεI respectively. The theoretical results are validated through illustrative examples and counterexamples.

Analysis of a Machine-Repair Problem Subject to Various Forms of Disasters

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Abstract: We analyze a machine repair problem subject to various forms of disaster. In this study, two distinct disaster scenarios are considered. In the first scenario, a disaster results in the failure of only a single machine, while the remaining machines continue to operate normally. In the second scenario, a more severe disaster is assumed in which all machines in the system fail simultaneously. Since manufacturing, industrial, healthcare, communication, transportation, and fleet maintenance systems are vulnerable to various forms of disaster. This model has great practical importance because it is more realistic than the classical machine repair problem. It helps to analyze the performance of real-life systems and supports better decision-making under uncertainty. In this model, disasters occur according to a Poisson process, whereas repair times follow an exponential distribution. There is a single repairman who repairs the machines on a first-come, first-served basis. The steady-state analysis of the model has been carried out in detail using the Kolmogorov-
forward equations. These equations describe changes in the system's state probabilities over time. Further, by applying a recursive approach, the probability distribution of the number of failed machines present in the system has been obtained. Based on this distribution, several important performance measures of the system are evaluated. These include the average number of failed machines in the system and in the queue, and the expected waiting time for failed machines in both the system and the queue. Finally, numerical and graphical results are presented to validate the analytical results.

A Mathematical Framework for Optimizing Drug Delivery Allocation using Machine Learning and Graph Theoretical Approaches

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Abstract: This study introduces a mathematical approach to identify target detection for optimizing allocation of drugs during outbreaks, ensuring rapid replenishment of life-saving medications. This framework can also be used routinely to address drug shortages and maintain a steady supply. In addition to this, the model enables the handling of non-linear data sets and efficient processing of complex and large-scale datasets. Incorporating graph coloring strategies may hasten up the computational process, leading to an automated system that substantially reduces logistical challenges and yields substantial benefits in terms of survival outcomes, lower operational cost and reduced processing time. Traditional drug delivery processes follow systematic planning revealing structure-function behavior however sometimes their implementation may be cumbersome at times. Hence, Machine learning technique thereby are increasingly being applied to forecast drug delivery targets and develop models of accurate structural frameworks. To incorporate graph coloring techniques, Supply chain management systems based on color coded graphs may be designed based on shortest path algorithms or minimum spanning tree methods can be used. Thereafter, models of supervised learning such as Random Forest or Support Vector Machines can lead to prediction of future needs of a drug at identified locations. Thus, the potential of integrating machine learning and graph theoretical approaches for drug delivery allocation, indicating a favorable future for the field arises. A visual interface through libraries such as D3.js or Folium can give an interactive color coded mapping of all areas with live data regarding stock levels, delivery status and forecasting of demand can get implemented. The findings may then offer a strong foundation for continuous research and advancement by researchers, academicians and pharmaceutical industries.

Robust Quasi-Approximate Optimality Paradigms for Bilevel Programming with Uncertain Data

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Abstract: This study examines robust nonsmooth bilevel programs involving uncertain parameters in both the objective and constraint expressions. A new concept of robust quasi-approximate solutions is proposed to effectively address uncertain data and to facilitate the formulation of approximate optimality conditions that remain stable under uncertain environments. Assuming appropriate constraint qualifications, Karush-khun-Tucker type necessary conditions are obtained for robust quasi-approximate solutions. Furthermore, sufficient optimality criteria are obtained. Numerical examples are developed to illustrate the effectiveness and applicability of the theoretical findings.

Transportation Problem in Fermatean Fuzzy Environment: An important Observation

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Abstract: Sahoo [RAIRO Oper. Res., 57,145–156, 2023] pointed out that there does not exist any method in the literature to solve Fermatean fuzzy transportation problems (transportation problems in which each parameter is represented by a fuzzy number). To fill this gap, Sahoo proposed a method to solve Fermatean fuzzy transportation problems. In this method, firstly, the considered Fermatean fuzzy transportation problem is transformed into a crisp transportation problem. Then, it is assumed that an optimal solution of the transformed crisp transportation problem also represents an optimal solution of the Fermatean fuzzy transportation problem. It is pertinent to mention that this assumption is valid only if the transformed crisp transportation problem is equivalent to the considered Fermatean fuzzy transportation problem. However, in this paper, it is shown that the transformed crisp transportation problem is not equivalent to Fermatean fuzzy transportation problem. Therefore, it is mathematically incorrect to assume that an optimal solution of the transformed crisp transportation problem also represents an optimal solution of Fermatean fuzzy transportation problem and hence, Sahoo's method is not valid.

Optimizing a Fully Rough Interval Integer Solid Transportation Problems: An Important Observation

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Abstract: AnithaKumari et al. [J. Intell. Fuzzy Syst., 41, 24292439, 2021] proposed an approach to solve fully rough interval solid transportation problems. Shivani et al. [Hacet. J. Math. Stat., 52, 1408–1424, 2023] proposed an approach to solve fully rough interval transportation problems. Since, fully rough interval solid transportation problems is a generalization of fully rough interval transportation problems as well as much computational efforts are required to solve a fully rough interval solid transportation problem by Shivani et al.'s approach as compared to AnithaKumari et al.'s approach. So, researchers may prefer to use AnithaKumari et al.'s approach to solve real-life fully rough interval transportation/ solid transportation problems. However, after a deep study, it is observed that AnithaKumari et al.'s approach fails to find an optimal solution of fully rough interval transportation/ solid transportation problems. Therefore, it is inappropriate to use AnithaKumari et al.'s approach to solve fully rough interval transportation/ solid transportation problems. The aim of this paper is to make the researchers aware about the inappropriateness of AnithaKumari et al.'s approach.

Mond-Weir and Wolfe Duality for Higher-Order Semi-Infinite Variational Problems using Caputo-Fabrizio Fractional Derivatives

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Abstract: In this study, the classical notion of convexity associated with the Caputo–Fabrizio (CF) fractional derivative is extended to ϱ-convexity of order m. This concept is further generalized to ϱ-pseudoconvexity of type I and type II of order m, as well as to ϱ-quasiconvexity of type I and type II of order m. An example involving the CF fractional derivative is provided to illustrate ϱ-convexity of order m. The main objective of this work is to investigate sufficient optimality and duality conditions for semi-infinite variational problems involving the CF fractional derivative, where the associated functionals satisfy these generalized ϱ-convexity assumptions of order m. Wolfe-type and Mond-Weir-type dual formulations are developed, and several duality results are established. In addition, an illustrative example is presented to demonstrate the weak duality theorem for the Wolfe-type dual problem.

Nonmonotone Steepest Descent Methods for Set Optimization Problems with Finite Set-Valued Map

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Abstract: In this work, we propose max-type, average-type, and modified-type nonmonotone steepest descent methods for unconstrained set-valued optimization problems with a lower set-less ordering relation. This relation is induced by a closed, convex, pointed, and solid cone. The objective map of the problem is assumed to have a finite collection of continuously differentiable functions. In order to capture a weakly minimal solution, a family of vector optimization problems is constructed at a candidate point. Then we use the equivalence optimality criterion between the original problem and the constructed family of vector optimization problems at that point in order to determine whether the candidate point is a weakly minimal solution of the original problem or not. Thereafter, we discuss the stationary condition using the above criterion. If that point is nonstationary, we find the steepest descent direction. Subsequently, the step length is computed using different nonmonotone line searches (max-type, average-type, or modified-type), which allow the increase of the objective function values at some iterations. Finally, we establish the convergence of the proposed methods without imposing any regularity condition on the optimal solution. In addition, this work also improves the existing steepest descent method for the set-valued optimization problems by removing the regularity assumption. We demonstrate the performance of the proposed method on some test problems and compare it with the existing steepest descent method for set-valued optimization problems.

Conditional Gradient Method for Set Optimization Problems

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Abstract: In this work, we propose the conditional gradient method, also known as the Frank-Wolfe method, for constrained set optimization problems. The objective map under consideration is defined by a finite collection of continuously differentiable functions. The problem is formulated with respect to a partial order set-less relation. Specifically, the lower and upper set-less relations are employed to compare objective values, and the proposed method is applicable under either of these relations. These relations are induced by a convex, closed, solid, and pointed cone. Within this

framework, the notion of a weakly minimal solution is examined, and a corresponding concept of stationarity is introduced. Thereafter, an auxiliary subproblem based on the Drummond–Svaiter scalarizing function is formulated. This leads to an equivalent stationarity criterion and provides a procedure for computing a descent direction whenever the trial point is non-stationary. Two step-size strategies–Armijo and adaptive step-size rules–are proposed to ensure sufficient descent. The adaptive strategy is established under a Lipschitz-type convexity assumption on the functions defining the objective map. The convergence of the proposed algorithm is discussed without imposing any regularity condition on the solution set. Furthermore, under suitable assumptions on the objective map, iteration-complexity bounds are derived. The proposed method is applied to several test problems to illustrate its performance and demonstrate its effectiveness in solving the constrained set optimization problems.

On Random Weighted Coherent Systems Based on a New Structure-Based Performance Measure

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Abstract: The performance level of a random weighted r-out-of-n system is measured by its total capacity. However, this measure is not meaningful for an arbitrary coherent structure as it does not involve the structure of the system. To overcome this drawback, we introduce here a new notion of performance measure (namely, the structural capacity) and then define three different notions of random weighted coherent systems, namely, Type-I, Type-II and Type-III systems. We then derive explicit formulas for computing the reliabilities of these systems. We further give a signature-based reliability representation for these systems. Further, we derive the Birnbaum marginal and joint reliability importance measures for the components of these systems and subsequently provide an algorithm for computing the same. Then, we study several ordering results based on these importance measures. For the Type-III random weighted coherent system, we introduce a new structure-based weighted importance measure and provide an algorithm for its evaluation. The developed results are illustrated through several numerical examples. Finally, we carry out the reliability estimation for a random weighted coherent system using two different simulated data sets.

Semi-Markov Modelling Approach for the Reliability Analysis of Multiple High Altitude Platform Station System

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Abstract: High Altitude Platform Stations (HAPS) are envisioned as a solution for wide-area coverage and resilient communication networks by positioning wireless infrastructure in the stratosphere at approximately 20 km altitude [Fuzzy Inf. Eng., 17, 154–176, 2025]. Compared to traditional communication satellites, the lower altitude of HAPS enables direct mobile communication services to smart-phones, similar to those utilized in fourth-generation Long Term Evolution (4G LTE) and fifth-generation New Radio (5G NR) base stations. Give the extensive reach of mobile broadband and the potential role of HAPS as a backup during emergencies, these systems are expected to significantly enhance network capacity in the future [Math. Comput. Simul., 215, 578–606, 2024]. This study explores the deployment of multiple HAPS within a single network to deliver fast, stable, and efficient connectivity across a designated region, thereby improving both reliability and capacity in critical areas. To ensure the effectiveness of a multi-HAPS system, conducting a comprehensive reliability analysis is crucial. As the demand for higher data rates and improved performance grows, evaluating system reliability becomes increasingly important. This research applies a k-out-of-n system approach to assess the reliability characteristics of multiple HAPS operating within a 5G NR framework. While conventional reliability studies often rely on k-out-of-n models and Markovian techniques for repairable systems, this work proposes an enhanced methodology ([Analytical Decision Making and Data Envelopment Analysis, Springer, 22, 259–279, 2024], [Int. J. Comput. Sci. Eng., 27,458–471, 2024]). By utilizing a Semi-Markov Process (SMP), the study examines the operational probability of HAPS units after system failures. The SMP approach offers a more refined analytical capability than traditional methods, particularly in accounting for time-dependent variations in failure probabilities when sojourn times deviate from an exponential distribution. Furthermore, the study evaluates the effectiveness of the proposed model by analyzing steady-state probability, availability, reliability, and mean time to failure.

Optimal Impedance Analysis of Human Lung using Fractional Order Model

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Abstract: This paper will present optimal impedance of human lung using fractional order differential equation. The viscoelastic properties of the human-airway's mechanics are based on the analogy to a current flow in electric circuit. Integer based differential equation of viscoelastic is unable to predict the correct flow physics of human lungs therefore, fractional order differential equation (FODE) is required to discussed. Fractional order models are acknowledged on the measured resistance to quantify the lungs mechanical properties. Caputo method is used to solved fractional order differential equations since it allows for traditional initial physical conditions. Results shows that airflow dynamics of human lungs and tissue are greatly affected by breathing flow rates (during running and exercise). The obtained results are very useful for the medical practitioner to diagnose and treatment of respiratory diseases.

Reliability Analysis and Effect of Propagation Failure on High Altitude Platforms in Wireless Communication

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Abstract: With the rapid advancements in Internet of Things, high-altitude platforms (HAPs) are revolutionizing various sectors, particularly in the realm of communication networks. As HAPs continue to exert their transformative influence across multiple domains, the aspect of reliability assumes a pivotal role in determining their triumph and widespread acceptance. The proposed study presents a comprehensive reliability analysis of HAPs using stochastic modeling. The investigation focuses on two distinct types of failures affecting a HAP: local failure (LF) and propagation failure (PF). To assess the reliability of the system employing a redundant HAP in the presence of these two failure types, a stochastic model has been developed. Considering the non-Markovian nature of the PF, the proposed model incorporates Markov and semi-Markov

processes. Through extensive numerical examples, the presented study explores the influence of failure propagation probability on system reliability and throughput. This analysis provides insights into how the system's reliability and overall performance are affected by the likelihood of failure. Furthermore, the study offers a comparative analysis of the results obtained from the Markov and semi-Markov models which provides a deeper understanding of the strengths and limitations of each modeling approach, enabling them to make more informed decisions in practice.

Modeling and Analysis of a Versatile Bulk-Service Queue with Group Arrivals and State-Dependent Essential and Optional Service

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Abstract: This article analyzes a stochastic queueing system where customers arrive in groups and wait in a finite queue to be served in batches by a single server. The system provides two stages of service: a compulsory essential service followed by an optional service selected by some customers. After completing the essential service, each customer independently decides whether to proceed to the optional stage according to a binomial selection rule in [Methodol. Comput. Appl. Probab., 26, 46, 2024]. The essential service follows a versatile bulk-service policy in [Qual. Technol. Quant. Manag., 24, 683–726, 2025]. At the beginning of each service period, an admissible batch size is randomly selected from predefined limits, and customers from the waiting queue, up to this admissible size, are taken together for service. Service times for both stages follow general distributions and may change only at the service initiation epoch, depending on the system state characterized by the queue length and serving batch size. Using the supplementary variable technique together with an embedded Markov chain approach, steady-state measures are obtained, including the joint probability distribution of queue length and serving batch size at arbitrary and service completion epochs. Finally, a numerical optimal control analysis evaluates how service parameters influence the total system cost.

A Comparative Study of Heuristic Approaches for Large-Scale Traveling Salesman Problems

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Abstract: Combinatorial optimisation problems, particularly the Traveling Salesman Problem (TSP), play a central role in operations research, theoretical computer science, and logistics network design. Despite its conceptual simplicity, the TSP is NP-hard, meaning that exact solution methods such as Branch-and-Bound or Dynamic Programming become computationally intractable as the number of nodes increases. Consequently, for large-scale instances involving hundreds or thousands of cities, the focus shifts from finding exact optima to identifying high-quality approximations using meta-heuristic frameworks.

This paper presents a rigorous comparative evaluation of two distinct stochastic optimisation paradigms: Simulated Annealing (SA) and Genetic Algorithms (GA). We analyse their efficacy in navigating complex search spaces to locate global minima while avoiding entrapment in local optima. The study is conducted using benchmark datasets from the TSPLIB library, with problem instances ranging from 50 to 500 cities. We explicitly investigate the impact of control parameters, specifically the cooling schedule in SA and the mutation/crossover rates in GA on convergence behaviour. Furthermore, to address the inherent limitations of pure evolutionary strategies, we introduce a hybrid framework that integrates a local search operator (2-opt heuristic) into the Genetic Algorithm. Performance is quantified using two primary metrics: the relative percentage deviation from known optimal solutions and the computational time required to reach convergence. The results indicate a significant trade-off: while Simulated Annealing offers superior computational speed for smaller instances, the hybrid Genetic Algorithm demonstrates enhanced robustness and solution quality for high-dimensional landscapes. This research provides actionable insights for selecting appropriate algorithmic strategies in real-world applications such as vehicle routing, circuit board drilling, and supply chain management.

A Generalized Waist Problem: Optimality Condition and Algorithm

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Abstract: Many years ago John Tyrell a lecturer at King’s college London challenged

his Ph.D. students with the following puzzle: show that there is a unique triangle of minimal perimeter with exactly one vertex to lie on one of three given lines, pairwise disjoint and not all parallel in the space. The problem in literature is known as the waist problem, and only convexity rescued in this case. Motivated by this we generalize it by replacing lines with a number of convex sets in the Euclidean space and ask to minimize the sum of distances connecting the sets by means of closed polygonal curve. This generalized problem significantly broadens its geometric and practical scope in view of modern convex analysis. We establish the existence of solutions and prove its uniqueness under the condition that at least one of the convex sets is strictly convex and all are in general position: each set can be separated by convex hull of others. A complete set of necessary and sufficient optimality conditions is derived, and their geometric interpretations are explored to link these conditions with classical principles such as the reflection law of light. To address this problem computationally, we develop a projected subgradient descent method and prove its convergence. Our algorithm is supported by detailed numerical experiments, particularly in cases involving discs and spheres. Additionally, we present a real-world analogy of the problem in the form of inter-island connectivity, illustrating its practical relevance. This work not only advances the theory of geometric optimization but also contributes effective methods and insights applicable to facility location, network design, robotics, computational geometry, and spatial planning.

Spiral Escape Algorithm for Deterministic Exploration in Multi-Modal Nonconvex Optimization

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Abstract: We propose the Spiral Escape Algorithm (SEA), a deterministic modification of gradient-based optimization for smooth nonconvex objective functions. The method augments classical gradient descent with a rotational perturbation generated by a skew-symmetric operator. The resulting dynamics consist of a descent component and an orthogonal perturbation component, yielding bounded transverse motion near stationary regions. Using Lyapunov analysis, we show that the rotational component preserves the gradient-norm Lyapunov function, while the descent component ensures monotonic decrease under suitable conditions. An adaptive scaling law is introduced to control the magnitude of the rotational perturbation and ensure bounded dynamics. Numerical experiments on standard benchmark functions illustrate the ability of SEA to explore multimodal landscapes more effectively than classical gradient descent.

A Comparative Study of Maximum Flow Algorithms under Varying Network Densities

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Abstract: The maximum flow problem is a classical optimisation problem in graph theory with critical applications in transportation logistics, telecommunication routing, and supply chain management. Given a directed flow network with capacity constraints on edges, the objective is to determine the maximum feasible flow from a designated source vertex to a sink vertex. Although several algorithms have been developed to solve this problem, their practical efficiency depends strongly on the structural properties specifically the sparsity and density of the underlying network. This paper presents an empirical comparison of two fundamental maximum flow algorithms: the Ford-Fulkerson method (implemented using Depth-First Search) and its breadth-first search variant, the Edmonds-Karp algorithm. While both approaches theoretically compute the same optimal flow value, they differ significantly in their strategy for selecting augmenting paths and their worst-case time complexities. We analyse their performance on synthetically generated graphs with varying densities, ranging from sparse networks to highly connected dense graphs. The experiments systematically measure execution time, the number of augmenting paths required to reach saturation, and memory usage for networks of increasing size. Our results indicate that the Ford-Fulkerson method performs efficiently on small or moderately sparse graphs but exhibits unstable runtime behaviour on pathological instances with irrational capacities. In contrast, the Edmonds-Karp algorithm demonstrates more predictable performance due to its guaranteed polynomial time complexity of $O(VE^2)$. This study highlights how graph density influences computational cost and provides practical insights for selecting the appropriate algorithm in real-world network scenarios.

Portfolio Analysis using Deep Learning Models

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Abstract: Effective portfolio management requires bridging the gap between accurate price forecasting and robust capital allocation. This research proposes a unified framework that sequentially integrates deep learning-based prediction with heuristic optimization to construct risk-aware portfolios. First, we conduct a comparative analysis of ten predictive architectures on high-frequency financial data, identifying

that Recurrent Neural Networks, specifically Long Short-Term Memory (LSTM) and Gated Recurrent Unit (GRU) models, consistently outperform statistical, tree-based and transformer-based baselines in capturing non-linear market dynamics. A critical methodological component of this stage is the evaluation of descent algorithms, where we demonstrate that Adaptive Moment Estimation (Adam) provides superior convergence stability compared to standard Stochastic Gradient Descent (SGD) in noisy loss landscapes. To translate these predictions into actionable positions, we employ a Genetic Algorithm (GA) rather than traditional convex solvers. This evolutionary approach allows for a global search of the solution space, effectively avoiding the local optima that plague gradient-based methods when facing discrete trading constraints. Finally, the framework optimizes for five distinct risk paradigms–including Conditional Value at Risk (CVaR) and Mean Absolute Deviation (MAD), thereby enabling the programmatic generation of portfolios tailored to diverse investor risk appetites, ranging from aggressive growth to strict capital preservation.

Physics-Informed Neural Network for Pricing American Options under Liquidity Shocks and Regime-Switching Markets

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Abstract: We aim to develop a physics-informed neural network (PINN) framework for pricing American options in markets subject to liquidity shocks and regime-switching dynamics. The model captures transitions between liquid and illiquid market states and incorporates the early-exercise feature inherent to American options. Rather than relying on traditional grid-based numerical methods, we propose to embed the governing financial dynamics, terminal payoff conditions, and early-exercise constraints directly into the neural network training process. This approach is intended to enable flexible, mesh-free learning of option value functions while preserving the underlying financial structure of the problem. We plan to evaluate the performance of the proposed framework in terms of pricing accuracy, stability across varying market regimes, and its ability to compute key sensitivities such as Delta and Gamma. Through this study, we seek to establish PINNs as a scalable and robust alternative for solving complex option pricing problems involving liquidity shocks, regime switching, and free-boundary effects.

Optimization-Induced Variability in High-Dimensional Estimation under Stochastic Gradient Methods

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Abstract: Estimator uncertainty in statistical learning is conventionally attributed to noise in the data-generating process. However, modern optimization pipelines rely heavily on stochastic gradient methods whose inherent randomness may introduce additional variability into learned parameters. This work investigates the dual origins of estimator uncertainty by systematically disentangling statistical variability from optimization-induced variability under stochastic gradient-based training.

Within a controlled linear regression framework, we develop a structured empirical variance decomposition methodology that isolates variability arising from data realizations and that induced by stochastic optimization dynamics. By independently varying dataset instances and training seeds, we quantify the magnitude of each component and examine their interaction across dimensional regimes and optimization settings. A comparative analysis with deterministic full-batch gradient descent further isolates the contribution of algorithmic stochasticity. Additionally, tracking parameter variance throughout the optimization trajectory reveals the temporal evolution of optimization-induced uncertainty.

Our findings demonstrate that stochastic optimization can contribute non-negligibly to total estimator variance, particularly in higher-dimensional settings and under aggressive step-size regimes. The magnitude and persistence of this variability are shown to depend systematically on optimization hyperparameters and problem dimension.

These results indicate that estimator uncertainty cannot be fully explained by statistical noise alone, but must explicitly account for randomness inherent in the optimization procedure. By providing a principled empirical decomposition framework, this study advances understanding of uncertainty under stochastic optimization dynamics and highlights implications for optimization method design and reliability in high-dimensional learning systems. Overall, this work contributes toward a more comprehensive characterization of estimator uncertainty by explicitly integrating optimization dynamics into statistical variability analysis, thereby informing more robust algorithmic design and interpretation.

On the Performance of Quantum Approximate Optimization Algorithm on Structured Graphs Arising in Coding Theory

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Abstract: Quantum optimization algorithms, particularly the Quantum Approximate Optimization Algorithm (QAOA), have emerged as promising approaches for solving combinatorial optimization problems using near-term quantum devices. At the same time, structured graphs such as cyclic graphs and Tanner graphs play a fundamental role in coding theory and quantum error correction. Understanding the behavior of quantum optimization algorithms on such structured graphs is therefore of both theoretical and practical interest. This work investigates the application of QAOA to structured graphs arising naturally in coding theory. The aim is to study how structural properties such as sparsity, symmetry, and regularity influence the optimization process and the performance of the algorithm. Quantum circuit simulations will be used to implement QAOA on representative graph instances, and the behavior will be examined in comparison with general graph structures. The study seeks to provide insight into the role of graph structure in quantum optimization and to explore potential connections with problems arising in quantum error correction and fault-tolerant quantum computing. This investigation aims to contribute to a better understanding of the applicability of near-term quantum optimization algorithms to structured problems arising in quantum information and coding theory.

Hager-Zhang Conjugate Gradient Method for Set Optimization with Set-Valued Objective Map of Finite Cardinality

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Abstract: This work introduces a nonlinear Hager-Zhang conjugate gradient method for solving set optimization problems. The objective function under consideration is defined by a finite collection of continuously differentiable functions. Notably, the proposed approach imposes restrictions neither on the existence of a finite generator of the ordering cone nor on any regularity condition at the optimal solution. As a result, the proposed method holds considerable significance for both set optimization and vector optimization problems, with the latter serving as a special case of the former.

The study begins by discussing Wolfe line search conditions using Drummond-Svaiter scalarization function. Thereafter, we establish the existence of a step length satisfying the Wolfe line search conditions along a descent direction. The Hager-Zhang scalar conjugate parameter is introduced to derive the search direction for the proposed method. It is established that the direction generated by the proposed method is a descent direction. The well-definedness of the proposed method is given. Furthermore, we discuss some important results and a Zoutendijk-like condition to ensure global convergence. Subsequently, the global convergence of the proposed method is established in an asymptotic manner. Finally, numerical experiments on various test problems validate the practical performance and effectiveness of the proposed technique.

Estimation and prediction based on lower k-record values from the unit Weibull Distribution

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Abstract: The unit Weibull distribution has gained attention as a flexible bounded model for lifetime proportions and reliability data defined on the unit interval, particularly in applications where normalized lifetimes, degradation ratios, or fractional failure times are observed. When inference is based solely on lower k-record values—rather than complete samples—the standard likelihood approach is no longer applicable, necessitating a specialized inferential structure built on the correct joint density of lower k-record statistics. This study develops a comprehensive estimation and prediction framework for the unit Weibull distribution under the lower k-record sampling scheme. Maximum likelihood estimators are derived; however, their performance is shown to be sensitive in small samples and sparse record scenarios, motivating the adoption of Bayesian methods with suitably chosen gamma priors. Posterior distributions are obtained using a customized Metropolis—Hastings algorithm, facilitating both parameter estimation and predictive analysis. Classical prediction techniques, shrinkage-based estimators, and Bayesian predictive measures are explored through posterior predictive simulation. An extensive simulation study investigates bias, mean squared error, interval coverage, and the impact of prior strengthening on inferential stability. The findings indicate that Bayesian inference, combined with the lower k-record likelihood formulation, yields robust and reliable estimation, making it well suited for practical reliability and proportion-based lifetime modeling contexts.

Inventory Optimization in a Closed-Loop Supply Chain Model with Multi-Shipment Policies

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Abstract: Closed-loop supply chains (CLSCs) are gaining importance due to stricter environmental regulations, growing waste generation, and increasing concern over resource scarcity. A CLSC supports the collection and remanufacturing of used products. This study develops an analytical inventory optimization model for a two-echelon CLSC consisting of a manufacturer and a retailer, supported by a remanufacturer who collects and processes returned products. In this system, the manufacturer produces only new items, while the remanufacturer restores returned products to reduce waste and environmental impact. The model incorporates a multi-shipment policy in which the manufacturer and remanufacturer fulfil the retailer's demand through multiple deliveries within a production cycle. This policy reduces inventory holding costs and improves coordination between supply chain members. The proposed model jointly determines the optimal production cycle length, shipment frequency, selling price, and environmental investment level, while considering carbon emissions from production and inventory processes. Optimality conditions are derived, and sensitivity analysis is conducted to evaluate the effects of key cost and emission parameters. The results highlight that coordinated decision-making and planned environmental investment can improve both economic performance and environmental outcomes.

A Bi-Level Chance-Constrained Fermatean Fuzzy Multi-Objective Optimization Model with Application to Mess Menu Planning

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Abstract: Menu planning for institutional mess systems involves complex hierarchical decision-making under uncertainty, where nutritional adequacy, cost efficiency, and operational feasibility must be simultaneously addressed. In practice, imprecision in nutritional values, fluctuating prices, and variability in consumption patterns make deterministic optimization approaches inadequate. To address these challenges, this study develops a multi-objective bilevel chance-constrained optimization model under a fermatean fuzzy environment for mess menu planning. The upper-level decision maker, representing the institute administration, focuses on promoting student health

by maximizing protein intake and dietary fiber while minimizing total fat consumption. The lower-level decision maker, representing the mess manager, seeks to minimize overall food cost and wastage. All coefficients in the objective functions and constraints are modeled using triangular fermatean fuzzy numbers to capture higher-order uncertainty and hesitation. The proposed solution methodology develops a bilevel decision framework tailored to fermatean fuzzy environments. At each level, triangular fermatean fuzzy objectives are processed using a component-wise optimization scheme, while fuzzy constraints are reformulated through $\alpha\beta$ -cut representations. Interval-valued chance constraints are then converted into deterministic equivalents using a reliability-based chance-constrained mechanism with acceptability indices. To address objective interdependencies and dimensional complexity, a TOPSIS-based evaluation is applied, followed by fermatean fuzzy programming to obtain an efficient bilevel solution. A realistic case study involving common food items in a mess menu planning context demonstrates the applicability and effectiveness of the proposed framework. Furthermore, a comparative analysis with a neutrosophic programming-based approach is outlined to highlight the robustness and flexibility of the fermatean fuzzy model. The proposed framework provides a practical and adaptable decision-support tool for institutional meal planning and can be extended to other hierarchical decision-making problems under deep uncertainty.

Public Transit Joint Service Frequency and Fare Optimization Considering Passenger Route Choice Behaviour Under Elastic Demand

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Abstract: The study presents joint public fare and service frequency optimization urban transit networks with elastic demand. By modeling passenger’s strategic route choice and system level effects, the study propose a Mixed Integer Non-Linear Programming (MINLP) model designed to maximize social welfare. The objective is balanced against critical operational constraints, including fleet availability, budget limitations, and vehicle capacity. To address the computational challenges posed by non-convex bilinear terms in the model, the work employs advanced reformulation techniques using discretization and McCormick envelopes, ensuring global optimality within a tractable solution time. The methodology incorporates optimal strategy based transit assignment to capture realistic passenger boarding behavior, and develops specialized network representations for different fare structures, including a novel dynamic section cost assignment method based on cumulative distance traveled. The proposed framework is evaluated on the Sioux falls transit network under different fare structures, i.e, flat, network distance, beeline distance, and section-based pricing. Numerical experiments

analyze the sensitivity of the system to changes with critical service parameters like fleet size and operational subsidies. The results demonstrate that under limited fleet capacity, the model dynamically prioritizes high demand corridors to maximize ridership without incurring agency losses achieving ridership increases exceeding 220% over baseline conditions. Furthermore, the analysis highlights the critical role of subsidies introducing financial support decouples operational cost recovery from fare pricing, leading to significantly lower fare rates and a substantial increase in consumer surplus. With optimized fare and service frequency levels the model shows substantial improvement in ridership from current transit demand share. This integrated approach serves as a policy making tool for transit organizations. By fare and service frequency planning simultaneously, the proposed method enables an optimal allocation of operating resources towards high passenger service levels.

A Comparative Study of Deterministic, Stochastic, and Robust Optimization for Decision-Making Under Uncertainty

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Abstract: Many real-world optimization under uncertainty problems involve uncertain parameters such as processing time, demand, cost, or energy availability. Traditional deterministic optimization methods assume that these parameters are known and fixed. Although such methods are simple and computationally efficient, their solutions may perform poorly when real conditions differ from assumed values. To address uncertainty, stochastic optimization and robust optimization approaches have been developed. However, despite extensive research in this area, there is limited work that provides a clear and practical comparison of deterministic, stochastic, and robust optimization methods using the same problem setting. This lack of direct comparison makes decision-making difficult for beginners and practitioners. This paper presents a comparative study of deterministic optimization, stochastic optimization, and robust optimization for decision-making under uncertainty. A common task scheduling problem is considered, in which uncertainty is introduced in task processing times. Deterministic optimization is performed using nominal processing time values, stochastic optimization models uncertainty using probability distributions, and robust optimization considers worst-case variations within predefined bounds. To ensure a fair and honest comparison, all three approaches use the same decision variables, constraints, and evaluation scenarios, differing only in how uncertainty is modeled. Experiments are conducted using standard benchmark settings and multiple uncertainty scenarios. The results show that deterministic optimization performs well when

uncertainty is low but is highly sensitive to parameter variations. Stochastic optimization provides better average performance when reliable probability information is available, while robust optimization produces more stable solutions under uncertainty, though often at the cost of conservative performance. The key finding of this study is that no single optimization method is universally best, and the selection of an appropriate approach should depend on the level of uncertainty and the desired balance between performance and robustness. This study offers clear guidance for decision-making in optimization problems under uncertainty.

Fuel-Optimal Ascent Trajectory Design for Multi-Stage Launch Vehicles via Hybrid Pseudospectral-SQP Optimization

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Abstract: Achieving fuel-optimal ascent trajectories is a critical requirement for modern launch vehicle missions, such as those conducted by ISRO, where propellant savings directly translate to increased pay-load capacity. This research presents a high-fidelity optimization framework designed to transcend traditional gravity-turn and zero-lift heuristics, which often fail to exploit the full solution space of non-linear gravitational and aerodynamic dynamics. The problem is formulated using a 3-DOF point-mass model integrated with atmospheric density variations and Mach-dependent drag coefficients, where the state vector $x(t) \in R^9$ is governed by coupled first-order differential equations representing the kinematic position, the velocity dynamics influenced by thrust-to-mass ratios and gravitational-atmospheric acceleration, and the mass-flow rate proportional to thrust magnitude. To solve this highly non-convex optimal control problem, we employ a Legendre-Gauss-Radau (LGR) Pseudospectral collocation method to transcribe the continuous-time dynamics into a sparse Nonlinear Programming (NLP) problem. Using a 50-node grid, this results in approximately 600 decision variables and defect constraints. The resulting NLP is solved using a Sequential Quadratic Programming (SQP) algorithm, utilizing Karush-Kuhn-Tucker (KKT) conditions, merit functions, and BFGS Hessian updates to ensure rapid convergence and feasibility under stringent path constraints, including maximum dynamic pressure and aero-thermal heating limits. Numerical simulations conducted in MATLAB demonstrate a 12–15% reduction in propellant mass compared to standard industry benchmarks. Furthermore, a mesh-refinement study confirms grid-independent accuracy and active-set feasibility, proving the framework's robustness for mission-critical trajectory design.

Dynamic Traffic Flow Optimization via Reinforcement Learning

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Abstract: Urban traffic congestion remains a persistent challenge, largely because current signal systems rely on rigid, pre-programmed timers that cannot react to real-time spikes in vehicle volume. This research proposes a smarter, learning-based approach in which traffic lights act as intelligent agents that continuously observe their environment and adapt in real time. The aim of this study is to move away from fixed cycles toward a dynamic system that treats traffic flow as a continuous optimization problem. We address this using Reinforcement Learning (RL), where instead of following predefined rules, the system is guided by a global objective: minimizing the total number of vehicles waiting at red signals. Rather than relying on static timers, each intersection is modeled as a live environment that learns from every passing vehicle. The system processes real-time snapshots of traffic conditions—including queue lengths and vehicle arrival speeds—and makes split-second decisions, such as extending a green phase to clear dense clusters or switching signals to prevent congestion on other approaches. To further enhance efficiency, a pressure-based control mechanism is employed, prioritizing lanes where vehicle buildup is highest relative to downstream capacity. Simulation-based evaluations demonstrate that the proposed RL-driven framework significantly outperforms conventional sensor-based methods by reducing average waiting times and mitigating stop-and-go traffic patterns that contribute to accidents and environmental pollution. Overall, the results highlight the potential of reinforcement learning as a scalable and mathematically grounded solution for next-generation intelligent traffic management, offering a practical pathway toward more autonomous and sustainable urban transportation systems.

Mathematical Optimization Techniques in Data Science for Enhancing Efficiency and Practical Decision-Making

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Abstract: Data science is a field used to analyze vast volumes of data through different techniques to make information understandable and actionable. To understand data science, it is essential to have a good foundation in three key areas: statistics, linear algebra, and optimization. Optimization is a procedure used to find the most efficient solution to a problem, where the objective value may be minimum or maximum

depending on the requirement. It serves as a backbone in many areas of data science, including machine learning (ML), artificial intelligence (AI), operations research, and statistics. Optimization also aids business leaders in predicting strategic plans and helps governments derive appropriate solutions for human welfare through
proper data analysis. Despite the widespread application of data science methods, the current focus on optimizing computational resources and system performance remains limited. This creates a gap in practical efficiency, especially when working with large-scale datasets. The objective of this research is to examine how optimization techniques can improve computational efficiency, performance, and resource utilization in data science workflows. This paper discusses various optimization methods, including gradient-based optimization, derivative-free optimization, and hyper parameter tuning. These are explored within the context of applications such as resource allocation, supply chain and logistics, finance and marketing, and neural networks. The classification of these techniques is aligned with a structured data science pipeline, emphasizing data processing, model configuration, and analytical performance. The results indicate that optimization significantly enhances computational efficiency, reduces resource consumption, and improves scalability. Gradient-based methods are effective for large datasets, derivative-free techniques are useful when gradient information is unavailable, and hyper parameter tuning enables better system configurations with fewer evaluations. Overall, optimization acts as a bridge between mathematical theory and practical data science applications, enabling more efficient, scalable, and cost-effective solutions.

Graph Theoretic Modeling and Flow Optimization for Healthcare Networks

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Abstract: Network optimization is a fundamental area of operations research concerned with the efficient design and operation of complex networked systems, particularly in healthcare infrastructures such as hospital networks, emergency medical services, and medical supply chains. As healthcare systems grow in size and complexity, achieving timely, reliable, and cost-effective service delivery under practical constraints becomes increasingly challenging. Traditional optimization approaches often struggle with large-scale, dynamic, lack unified frameworks applicable across domains, and have limited practical implementation, especially in healthcare. This study addresses these gaps by developing and analyzing a unified graph-based optimization framework that models and optimizes flows of patients, ambulances, and medical supplies across

healthcare networks. Essential network data—including facility locations, travel times, capacities, and demand—are systematically collected and processed to formulate an efficient routing and flow optimization model. The solver processes this model to compute optimal flows and routing decisions, and the results are presented through tables or visual network maps to support operational decision-making. The framework is implemented in Python and MATLAB using standard graph-processing and optimization libraries, enabling practical simulation, solution computation, and visualization of optimal flows. The framework is validated through simulation-based experiments on representative healthcare network scenarios. Simulation results indicate noticeable reductions in routing time and operational cost, along with improved balance of patient and supply flows across hospitals. Computation times remained efficient even for large networks, validating its scalability. These findings confirm that integrating graph-theoretic modeling with software-based optimization provides a practical, robust decision-support tool for modern healthcare networks, enabling faster response times, lower operational costs, and improved care quality.

Uncertainty Quantification and Bayesian Optimization for Predicting Student Academic Performance under Noisy Data

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Abstract: Predicting student academic performance is an important task in modern education, as it helps institutions design effective learning strategies and provide timely academic support. However, most existing machine learning models focus only on producing accurate predictions and ignore how confident the model is about those predictions, which limits their practical usefulness in real educational environments.

This paper presents a probabilistic framework for student performance prediction by integrating Bayesian regression with uncertainty quantification and Bayesian optimization. Given an input feature vector x, the predictive distribution is modeled as:

$$p(x, D) = \int p(x, \theta) p(D) d\theta,$$

and the posterior distribution is obtained using Bayes' theorem:

$$p(D) = p(\theta) p(\theta) p(D).$$

Uncertainty is quantified by estimating the predictive mean and variance, defined as:

$$\mu = E[y],\ \sigma^2 = E[(y - \mu)^2].$$

In addition, Bayesian optimization is used for hyperparameter tuning by minimizing an objective function:

$$\theta^* = argmin\, L(f\theta).$$

The results indicate that the probabilistic model achieves comparable or improved predictive accuracy while providing meaningful uncertainty information. This makes

the predictions more trustworthy and suitable for real-world educational decision-making, and highlights the importance of uncertainty-aware modeling for robust and interpretable academic performance prediction systems. Overall, the proposed framework demonstrates practical feasibility and offers a scalable solution for uncertainty-aware educational analytics.

Convergence Analysis of the Classical Proximal Gradient Method for Convex Optimization Problems

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Abstract: We study composite convex optimization problems of the form

$$\min_{x \in R^n} f(x) + g(x),$$

where f is convex with Lipschitz-continuous gradient and g is a proper, lower semicontinuous convex function. We introduce a new adaptive accelerated proximal gradient method that couples Nesterov-type momentum with a provably stable variable step-size rule, removing the need for prior knowledge of the Lipschitz constant. In contrast to existing accelerated proximal schemes, our method permits time-varying momentum parameters under relaxed step-size conditions while retaining optimal convergence guarantees. Under mild assumptions on convexity and boundedness of level sets, we prove global convergence of the generated sequence. In the general convex setting, we establish the optimal O $(1/\ k^2)$ convergence rate for objective values. Under additional strong convexity assumptions, we derive explicit linear convergence rates and strong convergence of the iterates. Our analysis unifies and strictly extends several classical accelerated proximal algorithms, including FISTA-type methods, as special cases, and provides a unified framework for understanding adaptive acceleration mechanisms. Comprehensive numerical experiments on standard large-scale benchmark problems demonstrate systematic improvements in convergence speed, stability, and parameter robustness over state-of-the-art proximal gradient and accelerated methods. These results offer both new theoretical insights and practically effective tools for large-scale composite convex optimization.

Energy-Constrained Stochastic Optimization for Efficient Deep Learning in Smart Grid Systems

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Abstract: The increasing use of deep learning in smart grid applications such as short-term load forecasting, fault detection, and demand response has significantly improved system intelligence. However, the high computational complexity of modern neural networks results in excessive energy consumption, which restricts their practical deployment in large-scale and energy-sensitive power infrastructures. To address this challenge, this paper proposes an energy-constrained stochastic optimization framework for training deep learning models with improved efficiency and reliability. The learning task is formulated as a constrained stochastic optimization problem that minimizes the expected prediction loss while satisfying an energy consumption limit:

$$E(x, y)\left[L\left(f_{theta(x)}, y\right) \text{ subject to } E(theta) \leq E_{max}\right].$$

An adaptive stochastic gradient method with energy-aware regularization is employed:

$$\theta_{\{k+1\}} = \theta_k - n_k(\nabla L_k(\theta_k) + \lambda \nabla E(\theta_k).$$

Simulation results using real smart grid load datasets demonstrate that the proposed method reduces training energy consumption by up to 30% while maintaining high forecasting accuracy. The framework is scalable, robust to uncertainty, and suitable for real-time grid analytics. This work contributes to sustainable artificial intelligence for next-generation energy systems and supports national energy efficiency objectives.

Mixed-Uncertainty Optimization for Joint Bandwidth and Power Allocation in SD-WAN Networks

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Abstract: The fundamental idea of SD-WAN is to replace traditional WAN routers with software-defined edge appliances or virtual CPEs that create encrypted tunnels and use overlay protocols and algorithms to load-balance traffic across multiple network paths. A central operational problem in SD-WAN is the joint allocation of bandwidth and transmission power across multiple links, where allocation decisions influence both throughput and energy expenditure. Practically, networks are unpredictable for two main reasons: sometimes it's just like random traffic spikes, and sometimes it's intentional like someone using jammers or interfering with network. The problem is that current tools are too rigid. They either treat every glitch as a random accident or everything like a worst-case disaster. Because they can't handle the mix of both random noise and active threats. This work formulates joint bandwidth and power allocation as a mixed-uncertainty optimization problem which integrates stochastic and adversarial components a mathematical framework. The proposed model is cast as a min-max-expectation problem, where allocation decision minimize expected performance loss and maintaining resilience against bounded adversarial disturbances. This formulation connects stochastic programming, robust optimization, and saddle-point theory, and enables theoretical analysis of duality structure, convexity conditions, and solution existence. Numerical evaluations across various implemented SD-WAN environment scenarios demonstrate improved allocation stability, QoS consistency, and robust deployment against traffic surges and targeted interference in IoT devices when compared to completely stochastic and robust baselines. The results indicate that mixed-uncertainty formulations offer a systematic and practically viable approach for resource management in modern SD-WAN deployments.

Optimization of Resource Allocation in Educational ERP Systems using Binary Integer Linear Programming

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Abstract: The fundamental concept of modern Enterprise Resource Planning (ERP) systems is that a centralized software architecture integrates core institutional processes, replacing fragmented management tools to facilitate the seamless flow of information across departmental boundaries. A central operational problem in educational engineering management is the optimal allocation of finite resources—specifically classrooms, laboratories, and faculty time—where scheduling decisions directly influence both operational efficiency and academic throughput. In the real world, resource management is complicated by stochastic unpredictability, including specific constraint variability such as room capacity limits and dynamic resource availability such as sudden faculty unavailability. Conventional manual scheduling tools lack the requisite flexibility to manage this unpredictability; they frequently rely on heuristic methods that fail to converge on optimal solutions because they cannot process the combinatorial complexity of conflicting variables simultaneously. This work formulates the academic resource allocation challenge as a Binary Integer Linear Programming optimization problem, which integrates strict decision constraints and objective maximization within a unified mathematical framework. The proposed model functions as a high-precision constraint-satisfaction engine, where allocation decisions systematically minimize scheduling conflicts and idle infrastructure time while

maintaining resilience against institutional rules. This formulation bridges linear algebra, decision matrix theory, and operations research, enabling rigorous theoretical analysis of solution feasibility, optimality conditions, and computational scalability. Numerical evaluations across implemented ERP scenarios demonstrate superior timetable compactness, zero-conflict resolution, and maximized infrastructure utilization rates compared to traditional baseline methods. The results suggest that embedding exact optimization algorithms within ERP systems replaces heuristic uncertainty with mathematical precision, providing a scalable and operationally robust solution for modern educational administration, effectively maximizing institutional resources while automating the resolution of complex, multi-variable logistical challenges.

Optimization-Based Resource Allocation in Multi-Echelon Supply Chain Networks using Linear Programming

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Abstract: We study resource allocation problems in multi-echelon supply chain networks formulated using linear programming. The objective is to determine optimal production and transportation decisions that minimize total system-wide cost, including production and transportation costs, subject to capacity, demand, and flow balance constraints. The supply chain model consists of production plants, warehouses, and customers, representing a realistic distribution network. We formulate a linear programming model that jointly optimizes production quantities and transportation flows across different echelons of the supply chain. The proposed model identifies the most cost-effective production sources and transportation routes without exceeding capacity limitations while ensuring that customer demand is satisfied. In contrast to traditional allocation approaches based on fixed or heuristic decisions, the proposed optimization framework enables systematic cost reduction through mathematical modelling. The model incorporates transportation structure constraints to ensure feasible and efficient flow coordination between plants, warehouses, and customers. Under standard assumptions of deterministic demand and known cost parameters, the linear programming model guarantees a globally optimal solution. Numerical results demonstrate that the optimized allocation significantly reduces total operational cost and improves resource utilization when compared to non-optimized allocation strategies. The proposed approach provides a simple, practical, and reliable framework for supply chain resource allocation and can be effectively applied to real-world logistics and distribution planning problems.

Engineering Applications of Artificial Intelligence in Smart Infrastructure Systems

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Abstract: The rapid advancement of engineering systems has led to increasing complexity in design, operation, and maintenance, creating a strong demand for intelligent and adaptive solutions. Artificial Intelligence (AI) has emerged as a transformative technology with wide-ranging engineering applications, particularly in the development of smart infrastructure systems. The primary objective of this study is to examine how AI-based techniques can enhance efficiency, reliability, and sustainability in modern engineering infrastructure such as transportation networks, energy systems, and structural health monitoring. Despite significant progress in automation and monitoring technologies, a major gap exists in the effective integration of real-time data analytics with predictive decision-making models, as many conventional engineering approaches still rely on static models and reactive maintenance strategies. This limitation often results in delayed fault detection, inefficient resource allocation, and higher operational costs. To address this gap, a hybrid AI-driven framework is proposed that combines machine learning algorithms, sensor-based data acquisition, and optimization techniques to enable proactive system management. The proposed method focuses on real-time condition monitoring, predictive fault detection, and adaptive control to improve system performance, increase operational safety, and reduce infrastructure-related risks. Simulation-based evaluation and multiple case studies demonstrate that the AI-enabled approach significantly improves prediction accuracy, reduces system downtime, and optimizes resource utilization when compared to traditional methods. Additionally, the framework supports intelligent decision-making by continuously learning from incoming data patterns and dynamically adapting to changing environmental and load conditions. The results indicate that the integration of AI in engineering applications not only enhances technical performance but also supports sustainable development by minimizing energy consumption, reducing maintenance costs, and extending infrastructure lifespan. This study highlights AI’s strong potential as a core component in next-generation engineering systems and provides a structured direction for future research and practical implementation in smart infrastructure development.

Trajectory Optimisation in Aerospace using Reinforcement Learning

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Abstract: Trajectory optimization is a central problem in aerospace engineering, where the objective is to determine an optimal path for a vehicle while satisfying dynamic and operational constraints. Classical approaches based on optimal control and numerical optimization provide accurate solutions but often require high computational effort and detailed system modelling. In this work, trajectory design is reframed as learning process. Using a Reinforcement Learning (RL) framework, an autonomous agent learns to navigate toward a target by receiving rewards for fuel efficiency and penalties for violating safety constraints. This approach allows the system to discover effective flight paths through iterative experience, bypassing the need for complex, hand-coded manoeuvres. The results show that reinforcement learning can generate feasible and efficient trajectories with reduced online computation compared to traditional optimization methods. While RL solutions may not always guarantee global optimality, they offer flexibility and adaptability, especially in uncertain or nonlinear environments. This study highlights the potential of reinforcement learning as a complementary tool to classical trajectory optimization techniques and provides an accessible introduction to its application in aerospace trajectory design.

Routing Flow Analysis and Traffic-Aware Optimization for Congestion Reduction in Communication Networks

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Abstract: Network routing determines how data packets travel from a source to a destination through interconnected nodes. In practical systems such as computer networks or internet communication, multiple paths may exist between two nodes, similar to multiple roads connecting two cities. In this work, the routing process is examined by observing how data flows through a network when several paths are available. The initial routing behaviour is recorded under normal traffic conditions, where packets are forwarded using distance-based path selection. To evaluate performance under realistic conditions, network traffic is gradually increased, and routing behaviour is monitored. As traffic load increases, repeated selection of the same preferred path occurs, leading to congestion at intermediate nodes. This congestion results in increased transmission delay, packet loss, and inefficient utilization of

available network resources, indicating that distance-based routing alone is insufficient for heavily loaded networks. Based on these key findings, the routing process is re-evaluated by considering traffic distribution and network load during path selection. When traffic is spread across multiple available paths rather than a single shortest route, congestion is reduced and data flow becomes more balanced. The improvements include faster data transmission, reduced packet loss, and better utilization of network capacity. The contribution of this work lies in demonstrating, through routing flow examination, how congestion develops and how traffic-aware optimization improves network performance, highlighting the importance of incorporating network load into routing decisions for reliable and efficient modern communication networks.

Fixed Point Theory Approaches to Optimization in Educational Data Classification: A Survey of Iterative Techniques for Student Performance Prediction

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Abstract: Educational Data Classification (EDC) has emerged as a pivotal domain for enhancing pedagogical strategies through the analysis of large-scale student datasets. A central challenge within EDC is the accurate prediction of student performance, a task mathematically formulated as an optimization problem aimed at minimizing a loss function over a parameter space. While traditional gradient-based methods are widely used, they often su!er from slow convergence or entrapment in local minima. This survey investigates the application of Fixed Point Theory as a rigorous mathematical framework for optimizing these predictive models. The theoretical foundations where the optimization problem is recast are explored as finding a fixed point x^* of a mapping $T : H \to H,$ where H is a real Hilbert space, such that $x^* = T x^*$.
This paper provides a comprehensive review of iterative fixed point techniques utilized to solve the optimization problems inherent in training EDC algorithms. The convergence properties of classical and accelerated iteration schemes are analyzed, transitioning from the fundamental Banach Contraction Principle to more complex structures. Specifically, we examine the efficacy of the Mann iteration and extend the analysis to multi-step iterations. Furthermore, we discuss the proximal point algorithm and its relation to the resolvent operator for maximal monotone operators, which is critical for regularized regression in performance prediction. By bridging the gap between abstract fixed point theorems and practical EDC applications, this survey demonstrates that selecting appropriate iterative parameters and mappings significantly enhances the convergence rate and stability of performance prediction models, offering a robust alternative to standard heuristic optimization techniques.

Performance Analysis of an M/P H/1/N Queue with Alternating Environments and Finite Battery Storage

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Abstract: We consider the performance analysis of an M/PH/1/N queueing system in which the server consumes energy from a battery while serving customers under two distinct environmental regimes. The fluid inflow into the buffer is modulated by a continuous-time Markov chain with finite state space S. In the first environment, we assume that the net fluid rate is strictly positive, and the system remains in this state for an exponentially distributed time, after which an environmental switch occurs. Conversely, in the second environment, no energy is harvested, and the battery is drawn down at a negative rate during customer service until the environment switches back. This work is motivated by renewable energy-powered service facilities, such as Electric Vehicle (EV) charging stations, where fluctuating energy availability and consumption rates are critical constraints. We explicitly model energy shortages in two distinct configurations: off-grid systems, where a depleted battery triggers an immediate service interruption until harvesting resumes, and hybrid on-grid configurations, where the model quantifies the duration and frequency of grid reliance required to maintain uninterrupted service. Using Spectral decomposition methods, we derive the stationary distribution of the joint process. We provide closed-form expressions for key performance measures, including the mean queue length, blocking prob ability, and the mean waiting delay. In addition to these, expected idle time spent at the zero-energy boundary, battery overflow probability and the first two moments of the stored energy are also computed. These results provide a theoretical framework for optimizing battery capacity and evaluating the reliability of energy-constrained service infrastructures.

Performance Analysis of a Multi-Server Two-Way Communication Priority Retrial System

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Abstract: We consider a multi-server priority retrial queueing system with two classes of incoming calls and one class of outgoing calls. Incoming calls arrive according to independent Poisson processes. When a server becomes idle, it initiates an outgoing call after an exponentially distributed time. Service times are class-dependent, however, for each class, are independent, identically distributed exponential random variates.

Class 1 incoming calls have high priority over class 2 incoming calls and outgoing calls. If all the servers are already occupied with high-priority calls, new high-priority arrivals join the priority queue with a finite capacity K. If a high-priority arrival finds all the servers busy with a low-priority or outgoing call, it can preempt their service. If both low-priority and outgoing calls are being served, then an outgoing call will be preempted. Blocked or preempted low-priority customers enter a virtual orbit and retry for service after an exponentially distributed time with constant retrial rate γ. Any preempted outgoing calls leave the system. Under a preemptive resume priority discipline, we analyze the Markovian model using matrix-analytic methods. This model offers insights into the design and optimization of smart EV charging hubs, enabling a balance between emergency readiness, customer service quality, and grid-interactive operations under stochastic demand conditions. In the EV charging station context, emergency vehicles are modeled as high-priority customers with preemptive access to charging resources, while private and fleet vehicles are treated as low-priority retrial customers that may leave the system and attempt service again if blocked. In addition to vehicle arrivals, servers initiate outgoing calls in the form of grid-support operations when chargers are idle. These grid-support activities are fully preemptible and are immediately terminated whenever higher-priority vehicle charging demands arise.

Quantum Classical Hybrid Approaches for Multi-Objective Supply Chain Logistics

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Abstract: Supply chain logistics optimization is a multi-objective optimization problem where we have to optimize different aspects namely scheduling, routing and network design simultaneously. Solving scheduling, routing and networking problems for supply chain logistics is NP-Hard problem and researchers are working on this topic by presenting approximation algorithms by implementing through classical computers. Quantum computing has the potential to revolutionise the field of computational logistics and supply chain management. But real scenario is that no one of scheduling, routing and networking problems can be directly solved on quantum annealers because of hardware limitations of the existing quantum annealer. Although in literature, some articles described quantum approaches to routing, logistic network design, and scheduling problems, in this article we study these problems through hybrid quantum-classical computing by representing supply chain as weighted directed graphs. Firstly, we design a supply chain to a directed weighted graph where each edge contains weight vectors corresponding to each aspect in relation with the optimization of supply chain logistic. Secondly, we determine multi-objective shortest path of these weighted graphs by classical-quantum hybrid approaches and using two types of scalarization-(a) Scalarizations of each weight vector and (b) Scalarizations of objective functions

corresponding to different parameters. Quantum annealing and gate-based quantum computing with Quantum Approximate Optimisation Algorithm and Quantum Annealing algorithmic approaches will be applied to determine multi-objective shortest paths.

The Filter Trust-Region Method for Unconstrained Vector Optimization Problem

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Abstract: We propose an algorithm based on a trust-region method for solving unconstrained vector opti mization problems with respect to partial order induced by general closed, convex, pointed, and solid cone. The proposed algorithm employs a filter strategy, initially introduced by Fletcher and Leyffer, which allows for non-monotone progression during the optimization process. Building on the filter im provement proposed by Fatemi and Mahdavi-Amiri, we incorporate a refined filter acceptance criterion that enhances both the efficiency and compactness of the filter set. This work extends the filter-based trust-region framework to the multiobjective setting, adapting it to the structure of vector-valued optimization problems. The resulting algorithm exhibits behavior analogous to that observed in the scalar case. We also provide a proof of the boundedness of the filter size.
Under some reasonable hypotheses, two distinct convergence analyses are provided. First, we show that at least one limit point of the sequence of iterates is first-order critical. Second, for a modified version of the proposed algorithm, we prove the stronger result that all limit points are first-order critical. Moreover, under suitable additional conditions, that near a solution the approximation error between the true Hessian and the model Hessian vanishes, we demonstrate that all limit points are second-order critical. Numerical experiments illustrate the efficiency of the proposed algorithms.

Canonical Formulations for Hub Arc Location Problems

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Abstract: Hub-and-spoke networks are used in the operations of multiple sectors like Transportation, Power Distribution, and Telecommunication. Flow from an origin spoke node is routed through intermediate nodes called hubs on the way to their destination spoke nodes. Since multiple origin and destination spoke nodes are connected to fewer hubs, the hub-hub transshipment carries huge amount of flows

leading to economies of scale. In literature, researchers have predominantly studied hub location problems in which hub nodes are located in a network to minimize cost (p – hub median problem), minimize the maximum distance travelled (p – hub center), or to maximize the demand covered (p – hub maximal covering problem). One drawback of this approach is that the economies of scale are uniformly applied over all hub arcs irrespective of the flow through it. To address this, we study hub arc location problems in which transshipment arcs (hub arcs) are located as opposed to hubs thereby allotting economies of scale only to select hub arcs. The Hub Arc Location Problem presents a challenging combinatorial optimization problem in network design that aims to select exactly p hub arcs in the network to minimize total transportation costs. The objective of this paper is to develop a canonical integer programming formulation for this problem that improves computational efficiency and broad applicability by reducing restrictive assumptions common in existing hub location models. We further present an accelerated Benders Decomposition Approach to solve large scale instances of the problem.

Viscosity Method with a weakly contraction mapping for Hierarchical Variational Inequal ities: Discrete and Continuous Perspective

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Abstract: This paper investigates a hierarchical variational inequality problem (HVIP) over the set of common fixed points of a family of strictly pseudocontractive mappings. The problem involves a Lipschitz continuous and strongly monotone mapping combined with a weakly contraction mapping. Two solution approaches are proposed. First, we design a viscosity-type iterative algorithm that incorporates a weakly contractive mapping and prove that the resulting sequence converges strongly to a solution of the HVIP. Second, we introduce a viscosity-type dynamical system with a weakly contraction mapping and establish the strong convergence of its trajectories to a solution of the HVIP. Finally, we provide numerical examples to validate our analytical methods.

Constrained Multi-Objective Evolutionary Optimization of a Nonlinear Bootstrap Air Refrigeration Cycle Incorporating Thermodynamic Feasibility and Turbine Outlet Temperature Limits

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Abstract: This paper presents a constrained multi-objective evolutionary

optimization framework for a nonlinear bootstrap air refrigeration cycle employed in aircraft Environmental Control Systems (ECS). The problem is formulated as a nonlinear constrained vector optimization model in which compressor pressure ratios r_{c1}, r_{c2} , and heat exchanger effectiveness ϵ, serve as decision variables. The governing thermodynamic relations introduce strong nonlinear coupling between state variables, while feasibility is enforced through
inequality constraints on turbine outlet temperature ($T_7 \geq 230K$), minimum heat exchanger approach temperature, and total pressure ratio bounds. A physics-consistent thermodynamic model incorporating compressor and turbine isentropic efficiencies, ram pressure recovery, and distributed heat exchanger pressure losses is first validated under representative cruise conditions (10 km altitude, 250 m/s flight velocity, 120 kW cooling load). Monte Carlo sampling over 20,000 design points reveals that only 1.15% of the admissible decision space
satisfies all constraints, indicating a highly restricted feasible manifold embedded within a larger nonlinear search domain. Within this feasible region, the model predicts a coefficient of performance (COP) range of 0.512–1.58 and bleed mass flow between 0.813–1.084 kg/s, while strictly maintaining thermal safety margins. The optimization problem is then solved using a Non-dominated Sorting Genetic Algorithm (NSGA-II) to simultaneously maximize COP and minimize both bleed mass flow and turbine outlet temperature. Penalty-augmented objective functions are employed to preserve constraint admissibility during evolutionary search. The resulting Pareto frontier exhibits a convex trade-off structure, demonstrating intrinsic coupling between thermodynamic efficiency and constraint-bound thermal behaviour. Designs achieving maximal COP cluster near the turbine outlet temperature boundary, confirming that system performance is constraint-limited rather than unconstrained efficiency-driven. The proposed formulation provides a mathematically rigorous framework for analysing nonlinear constrained thermodynamic systems and demonstrates the applicability of evolutionary multi-objective optimization in engineering design spaces characterized by narrow feasible regions.

A Newton-type Proximal Gradient Method for Uncertain Vector Optimization Problems with Finite Uncertain Scenarios

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Abstract: In this work, we propose a new framework for solving uncertain multiobjective optimization prob lems by converting them into an equivalent set-valued optimization formulation. We consider uncertainty only in the objective functions and assume that the uncertainty set is finite. For each possible scenario, the objective function is expressed as the sum of two parts: a twice continuously differentiable locally strongly convex function and a continuous function that may be nonsmooth.

To compute robust weakly efficient solutions, we develop a Newton-type proximal gradient algorithm. The proposed approach employs the notion of a partition set from set optimization, which allows us to construct a collection of associated vector optimization problems. These problems are then used to generate the iterates of the proposed Newton-type proximal gradient scheme. We prove that the method produces a convergent sequence whose limit corresponds to a weakly robust efficient solution.
Moreover, an Armijo-type line search strategy is incorporated to determine an appropriate step size at each iteration. Under mild assumptions, local convergence results are established. Finally, a numerical experiment is presented to demonstrate and evaluate the effectiveness of the proposed method.

Trust Region Method for Vector Optimization in Variable Ordering

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Abstract: We proposed an extension of the trust-region method for unconstrained vector optimization problems under a variable ordering structure. In this approach, the subproblem is constructed using a quadratic approximation of the scalarized objective function. Similar to previous work done by Gabriel A. Carrizo,Pablo A.Lotito and Mariciel for multicriteria, a trust-region subproblem is solved at each iteration, and the resulting trial step must be evaluated. Consequently, the concepts of actual decrease and predicted reduction are reformulated to suit the vector optimization framework. Under standard assumptions, the proposed algorithm is shown to converge to a point that satisfies a necessary condition for Pareto optimality.

A Quasi-Newton Method for Solving Uncertain Multiobjective Optimization Problems with Finite Uncertainty Sets

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Abstract: We develop an iterative scheme based on a quasi-Newton technique to identify robust weakly efficient points of uncertain multiobjective optimization

problems under the upper set less relation. The uncertainty set is assumed to have finite cardinality, and for each uncertainty scenario, the corresponding objective functions are assumed to be twice continuously differentiable. At each iteration, we employ the partition set concept from set-valued optimization to formulate an iterate-dependent class of vector optimization problems for determining a descent direction. To compute this direction at the current iterate, one step of a quasi-Newton method for vector optimization is applied to the formulated class of problems. Since this class of vector optimization problems varies from iteration to iteration, the proposed quasi-Newton scheme is not a direct extension of existing quasi-Newton methods for vector optimization. Under standard assumptions, we show that any accumulation point of the sequence generated by the proposed method is a robust weakly efficient solution of the problem. Furthermore, we investigate the well-definedness and global convergence of the algorithm under a regularity condition on stationary points. Under the additional assumption of uniform continuity of the Hessian approximation, we establish the local superlinear convergence of the proposed method. Finally, numerical examples are provided to illustrate the effectiveness of the algorithm.

Steepest Descent Method for Multiobjective Optimization Problems of Interval-Valued Maps

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Abstract: In this article, we propose a steepest descent method for unconstrained multiobjective interval optimization problems (MIOPs). After establishing a relationship between weakly Pareto optimal points and Pareto critical points of an MIOP, we develop an algorithm to find a Pareto critical point of the MIOP. In this algorithm, we provide the computation of a descent direction at a non-Pareto critical point for an MIOP. Further, we use Armijo-like rule to find the step length. We prove the existence of the step length and derive an estimation of its lower bound. Under certain assumptions, we prove that the sequence generated by the proposed algorithm converges to the Pareto critical point of the MIOP. In addition, we show that our proposed algorithm has a rate of convergence of $O\left(\frac{1}{\sqrt{k}}\right)$ for nonconvex, $O\left(\frac{1}{k}\right)$ for convex, and and $O(\gamma^k)$ for some $\gamma \in (0,1)$ for strongly convex multiobjective interval-valued mappings. Finally, we provide numerical validation and performance of our proposed algorithm through some test problems.

Variable Neighborhood Search for the Multi-Depot Multiple Set Orienteering Problem

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Abstract: This paper introduces a variant of the Set Orienteering Problem (SOP), termed the Multi-Depot Multiple Set Orienteering Problem (mDmSOP). The proposed mDmSOP generalizes the classical SOP by grouping nodes into mutually exclusive sets (clusters) with associated profits, where profit is earned if at least one node within a set is visited. Unlike the traditional single-depot setting, multiple travelers ($t > 1$) are considered, each associated with a distinct depot. The primary objective is to maximize the total collected profit from the sets while satisfying predefined travel budget constraints for each traveler. A novel mathematical formulation for the mDmSOP is presented, extending the structure of existing SOP and GTSP-based models. To efficiently solve the problem, we employ the Variable Neighborhood Search (VNS) meta-heuristic, incorporating tailored shaking and local search strategies suitable for clustered and multi-depot settings. Computational experiments are conducted on small, medium, and large benchmark instances derived from the Generalized Traveling Salesman Problem (GTSP) dataset. The results demonstrate that the proposed VNS approach is robust and capable of producing high-quality solutions within significantly lower computational time compared to solving the exact mathematical formulation using GAMS 37.1.0 with CPLEX. Furthermore, experimental analysis shows that increasing the number of travelers substantially enhances the total collected profit, highlighting the practical advantage of the multi-depot multi-traveler configuration. Overall, the proposed formulation and VNS framework provide an effective and scalable solution methodology for large-scale mDmSOP instances.

Exploring the Performance of Genetic Algorithm and Variable Neighborhood Search for Solving the Single Depot Multiple Set Orienteering Problem: A Comparative Study

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Abstract: This article discusses the Single Depot multiple Set Orienteering Problem (sDmSOP), a recently suggested generalization of the Set Orienteering Problem (SOP). This problem aims to discover a path for each traveler over a subset of vertices, where each vertex is associated with only one cluster, and the total profit made from the clusters visited is maximized while still fitting within the available budget constraints. The profit can be collected only by visiting at least one vertex from a cluster, and the number of clusters visited is restricted by the available budget for tour expenses. To address this problem, we employ the Genetic Algorithm (GA) and Variable Neighborhood Search (VNS) meta-heuristics. The optimal solution for small-sized problems is also suggested by solving the Integer Linear Programming (ILP) formulation using the General Algebraic Modeling System (GAMS) 37.1.0 with CPLEX for the sDmSOP. Promising computational results demonstrate substantial improvements in solution quality obtained by VNS compared to GA, while requiring significantly less computational time than CPLEX. Evaluation on GTSP-derived benchmark instances shows that VNS consistently yields higher profits across diverse instance sizes and scales better as the number of travelers grows. The ILP approach provides optimal solutions only for very small instances and becomes computationally infeasible as problem size increases. These findings offer valuable insights into designing scalable and effective solution strategies for the sDmSOP and related routing problems, suggesting that VNS approach can enhance search effectiveness over traditional evolutionary approaches like GA.

A Flexible Modeling of Extremes in the Presence of Inliers

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Abstract: Many random phenomena, including life-testing and environmental data, show positive values and excess zeros, which pose modeling challenges. In life testing, immediate failures result in zero lifetimes, often due to defects or poor quality, especially in electronics and clinical trials. These failures, called inliers at zero, are difficult to model using standard approaches. The presence and proportion of inliers may influence the accuracy of extreme value analysis, bias parameter estimates, or even lead to severe events or extreme effects, such as drought or crop failure. In such scenarios, a key issue in extreme value analysis is determining a suitable threshold to capture tail behaviour accurately. Although some extreme value mixture models address threshold and tail estimation, they often inadequately handle inliers, resulting in suboptimal results. Bulk model misspecification can affect the threshold, extreme value estimates, and, in particular, the tail proportion. There is no unified framework for defining extreme value mixture models, especially the tail proportion. This paper proposes a flexible model that handles extremes, inliers, and the tail proportion. Parameters are estimated using maximum likelihood estimation. Compared the proposed model estimates with the classical mean excess plot, parameter stability plot, and Pickands plot estimates. Theoretical results are established, and the proposed model outperforms traditional methods in both simulation studies and real data analysis.

A Hybrid Approach to ESG Based Financial Portfolio Management using Bayesian Optimization and Deep Reinforcement Learning

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Abstract: Background and problem**:** Traditional portfolio management models like Markowitch mean-variance framework fail to incorporate Environment, social and Governance (ESG) criteria and rely on restrictive assumptions. The paper proposes to include financial risk factors with ESG parameters through a multi objective Bayesian optimization adding novelty to the approach. The hyperparameter tuning problem of DRL perfectly suits the Bayesian process. The ESG variables are added in the state space. By considering the weights of both components, the multi objective based portfolio is developed to suit the investor's needs.

Proposed Methodology: The paper introduces hybrid methodology combining multi objective Bayesian optimization with Deep Reinforcement learning (DRL). The reason for including the Bayesian approach is the fact that DRL has high variability and is sensible to the value of hyperparameters. The multi objective scenario is solved by modelling each objective with an independent probabilistic surrogate process like the Gaussian process. The methodology analyzes the financial risk factors through the Sortino ratio. The novelty also gets added through the Sortino ratio Unlike Sharpe ratio, which considers total volatility. Sortino ratio only calculates deviation from negative returns offering better measure of downside risk.

Results and Data Analysis: The data based on DOW JONES and NASDAQ 100 indexes from 2008 to 2022. For the ESG part, data is collected from the monthly Bloomberg. ESG information reported on a scale of 0 to 10. The experiments are conducted using Open AI gym adapted from the Fin RL platform.

Initial Findings and Contribution: The paper is in the working stage, but initial findings do support the superiority of MOBO over traditional random search methods. The initial findings do suggest that the algorithms develop a hypervolume based data which helps to reduce the number iterations and reduce computation unlike the random search processes.

A New Filled Function Method for Non-convex Multi-objective Optimization Problems With One-parameter

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Abstract: In this work, a new filled-function method with one-parameter is proposed for nonlinear multi-objective optimization problems. Filled function ideas from single-objective optimization are extended to the multi-objective setting to facilitate escape from local Pareto fronts and to promote progress toward the global Pareto front. Scalarization weights are not used, and no prior preference ordering among objectives is imposed. This method alternates between two phases. First, a descent-based step is used to compute a local weak efficient solution. Next, a filled function is constructed and applied to generate a new local weak efficient solution that improves the current one. These phases are repeated to drive the search toward global weak efficient solutions. In this way, the global Pareto front is approximated, even in non-convex problems with multiple distinct local Pareto fronts. Finally, numerical experiments on a set of non-convex multi-objective test problems are conducted to demonstrate robustness and computational efficiency.

Acceptance Sampling-Based Investment Indicator for Financial Security Selection and Portfolio Optimization

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Abstract: We propose a simple acceptance sampling investment indicator designed to determine the acceptance or rejection of financial securities for investment based on a tolerable threshold assessed through historical data. The indicator alleviates the burden of including underperforming securities in a portfolio and determines the optimal sample size required for decisions at a given significance level. The investment indicator is defined to address the perspectives of buyers and sellers of securities. The proposed simple acceptance sampling–based indicator makes investment decisions by analyzing each sample point. Furthermore, we develop a generalized mean–variance portfolio optimization model that includes the buyer's risk and entropy-based uncertainty in decision-making for selected securities. The applicability of these indicators and the model's generalizability are illustrated using DJIA 30 index stocks, showcasing a reduced portfolio size while producing equivalent or higher portfolio returns compared to the Markowitz model.

Approximation of *(k_1, k_2, …, k_m)*-events via Pseudo-binomial Distribution

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Abstract: In a sequence of mutinomial trials with outcomes *0,1, …, m-1*, we consider the event defined as "at least k_1 consecutive *0*'s followed by at least k_2 consecutive *1*'s, …, followed by at least k_m consecutive *(m-1)*'s." Although the exact distribution of this event can be established under independent and identically distributed (iid) trials, the problem remains analytically intractable for the non-iid setup. Therefore, we propose a pseudo-binomial approximation to *(k_1, k_2, …, k_m)*-events. Our results provide new theoretical insights and establish approximation bounds that, to the best of our knowledge, have not yet been studied for multinomial trials.

A Unified Deep Learning Framework for Solving Generalized-Order Differential Equations

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Abstract: Deep learning has emerged as a powerful tool for modelling, solving complex scientific and engineering problems. Physics-informed neural networks (PINNs) enhance neural network models by embedding physical laws to solve differential equations. However, standard PINNs often face challenges when applied to fractional differential equations due to the nonlocal nature of fractional derivatives and the use of fixed activation functions, which can limit their accuracy for complex nonlinear problems. To address these limitations, we proposed the Kolmogorov–Arnold Network (KAN) as a neural network solver. Unlike conventional fully connected neural networks used in PINNs, which rely on fixed activation functions, KAN uses learnable activation functions, allowing for a more flexible and expressive modelling of complex nonlinear relationships. The KAN architecture is inspired by the Kolmogorov–Arnold representation theorem, which provides a theoretical foundation for expressing multivariate functions as compositions of univariate functions. The KAN framework is used for both forward simulation and inverse parameter estimation of nonlocal time-fractional phase-field models governed by the Allen–Cahn and Cahn–Hilliard equations. Nonlocal phase-field models are widely used to describe complex physical phenomena such as phase separation and interfacial dynamics. Numerical results demonstrate that the proposed framework consistently outperforms standard PINNs in terms of reduced error and improved accuracy for both solution approximation and parameter estimation

in nonlinear and nonlocal governing equations.

Efficiency Analysis of Electric Power Companies via Rough Network SBM

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Abstract: This study develops a rough network slack-based measure (SBM) framework to evaluate performance under data uncertainty. The SBM is a non-radial approach that directly incorporates input excesses and output shortfalls into the efficiency score. SBM evaluates efficiency by maximising or minimising the sum of slacks, thereby capturing each dimension of inefficiency rather than a single proportional adjustment. An empirical application involving electric power companies is conducted to assess both the overall system efficiency and the performance of individual operational stages using the network SBM approach. The analysis emphasises the examination of internal processes in the presence of imprecise data, allowing inefficiencies within different stages to be identified. This formulation extends the theoretical foundations of network SBM under uncertainty. In the subsequent stage of the analysis, a regression model is employed to investigate the influence of context-specific external factors on efficiency outcomes.

Optimizing Sustainable Supply Chain Performance in the Soft Drink Industry

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Abstract: This research investigates the integration of Sustainable Supply Chain Management (SSCM) within the soft drink industry, specifically focusing on the Coca-Cola Company. As environmental and social pressures mount globally, firms are increasingly required to align their operational strategies with sustainable development goals. The study employs a qualitative case-study methodology to evaluate the adoption of green practices in purchasing, manufacturing, and logistics. A critical component of this analysis is the application of the Economic Order Quantity (EOQ) optimization model. By utilizing EOQ, the study demonstrates how the company can optimize inventory levels to minimize the trade-off between ordering and storage costs, thereby enhancing resource efficiency and reducing waste. The findings reveal that while many Indian firms adopt SSCM practices voluntarily or for regulatory compliance, external pressure from customers remains low. However, the integration of optimization techniques like EOQ, alongside sustainable product design and supplier collaboration, is shown to improve long-term competitiveness and economic performance. The study

concludes that top management commitment and the use of analytical frameworks are vital for transitioning toward a truly sustainable and efficient supply chain.

A framework for optimizing multicommodity transport in a military operations context

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Abstract: Military transport operations often involve mobilizing personnel and equipment and transporting them from hubs via land or air to forward bases from where the requirement for these originates. The key objective in such transport operations involves meeting the demand from all forward bases in as little time as possible. In this study, we present a framework for optimizing these operations under multiple scenarios. The first mixed-integer linear programming formulation within this framework considers demand for personnel and cargo that originate from multiple forward bases, and attempts to meet this demand in minimal time using aircraft of two types distributed across multiple transport hubs where the cargo and personnel are mobilized for transport. The formulation includes constraint that incorporate aircraft range, capacity in terms of weight, the number of available aircraft and aircraft travel time (back and forth). For this formulation, we also develop a simple greedy heuristic that solves the problem in substantially lesser time and returns high-quality solutions. The second formulation in the framework extends the first to the case where forward bases are outside the range of all available aircraft. In this case, refueling halts must be included in the formulation. For this formulation, we develop a logic-based Bender's decomposition solution approach for large-scale versions of the problem that considerably improve solution time.

A Statistical Assessment of the Impact of Machine Learning Inputs on the Performance of Integer-Valued Markowitz-Type Portfolios

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Abstract: The dynamic and volatile nature of financial markets requires decision tools that combine accurate stock movement forecasts with optimal portfolios derived from formulations that incorporate real-world trading constraints. This paper presents an integer-valued portfolio optimization framework that integrates next-day stock closing price predictions from machine learning (ML) models (XGBoost) into several

Markowitz-type formulations. We evaluate multiple formulations including diversification constraints, explicit short-selling models (standard and volatility-normalized / "Black-Scholes"-style), a Meta-Markowitz ensemble that hedges strategic risk across portfolios themselves, and a robust optimization variant under box uncertainty. Experiments on the Indian SENSEX constituent stocks (2010--2024 training window) show that ML-informed integer portfolios outperform the SENSEX and Markowitz-without-ML benchmarks with respect to five portfolio performance metrics including the Sharpe and Sortino ratios, while robust and meta strategies reduce downside risk. These experiments involve a comprehensive statistical analysis pipeline: Ljung-Box and augmented Dickey-Fuller tests for autocorrelation and stationarity prior to statistical comparison; Shapiro-Wilk tests of normality to determine whether nonparametric or parametric comparisons must be performed; and finally, a variety of parametric (Student's t) and nonparametric (Friedman, Wilcoxon signed-rank) tests to assess performance of each Ml-informed portfolio against the benchmarks.

A space-partitioning genetic algorithm for discrete optimization via simulation

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Abstract: In this study, we present a new genetic algorithm for discrete optimization via simulation. Such problems arise when objective function realizations (for a discrete stochastic optimization problem of the form are generated via a stochastic simulation. Here and is a finite and countable set. We propose a genetic algorithm, which we call the space-partitioning genetic algorithm (SPGA) for solving such problems that involves partitioning the solution space by constructing the Cartesian product of partitioning the one-dimensional spaces of individual decision variables. We then construct a genetic algorithm that works with these partitions in a exploration-exploitation paradigm. In each iteration, we retain solutions from high-performing partitions and randomly sample partitions to explore from the rest of the solution space. We exploit high-performing partitions by evaluating multiple generations of solutions from such partitions. We incorporate crossover via solution index exchanges and mutation also by perturbing solution indices. The partitioning approach helps keep track precisely of which regions of the solution space yield high-quality solutions. By increasing the number of replications recorded for each solution retained from one iteration to the next, we can guarantee asymptotic convergence in probability to the global optimal solution, and we provide theoretical support for the same. Finally, computational benchmarking experiments with the state-of-the-art genetic multi-armed bandit method and the adaptive hyperbox method on multiple test problems indicate consistently superior performance of the SPGA.

Optimal 3-dimensional path planning for aircraft with obstacles and aircraft performance constraints

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Abstract: In this study, we present an approach for planning optimal paths for aircraft from a start position to a goal position across a 3-dimensional map. The map, with obstacles and terrain features, is converted into a 3-dimensional grid, which then becomes suitable for applying network optimization methods such as the A-star method. We develop a modified version of the A-star method that takes aircraft performance constraints into account in generating the optimal path. The method involves using a map cost array, wherein costs are assigned to each grid cell, with substantially higher costs assigned to grid cells with obstacles (e.g., enemy radars) and terrain features (e.g., mountains) that need to be avoided. Aircraft performance constraints, such as minimum and maximum turn angles, turn radii, and minimum and maximum climbing angles, are incorporated into the map cost array by constructing expanded turn and climb contours around each obstacle at regular height intervals of the obstacle. The turn and climb contours also take into account obstacle shape characteristics. A best cost array, wherein the cost of each cell represents the minimum cost distance to the goal, is then constructed from the map cost array modified with such obstacle preprocessing. The optimal path is then found by applying the A-star network optimization method with a 3-dimensional fan-cone projected at each step to find the next best cost array cell on the path. The fan-cone is constructed to take turn and climb aircraft performance constraints and minimum route leg lengths into account while determining the optimal path. We illustrate the implementation of our approach with multiple computational experiments.

Failure prediction of engine through wear particle analysis using fractal techniques linked to artificial neural network

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Abstract: This article has been addressed the extensive and corrective information on the wear of machinery, such as root cause analysis of wear particles and how critical they are. Such data offer insights to serviceability experts regarding existing or potential failure. The authors here opine that the morphological characteristics and fractal dimensions of wear particles which is carryout through fractal computation technique. This technique performed to estimate the surface roughness of the particle boundary, which indicates the wear rate failure, has been highlighted. Finally, the fractal analysis application provides information on different wear particle characteristics. Fractal analysis application determines precisely the nature of roughness in wear particle. Since

the degree of roughness can determine the technical state of the machine, it is possible to detect the failure of any internal components of a CNG and diesel engine. To predict outputs, i.e., log (Perimeter) concerning log (length of steps), a neural network model was developed using feed-forward back propagation. The proposed neural network model is designed to analyse the output perimeter under the various length of the step platform. ANN predicted data could also be used to diagnose the faults and determine the prognosis maintenance time.

Bregman regularized proximal point methods for computing projected solutions of quasi-equilibrium problems

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Abstract: In this paper, we propose two Bregman regularized proximal point methods that provide flexibility to compute projected solutions for quasi-equilibrium problems. Each method has one Bregman projection onto the feasible set and the regularized equilibrium problem. Under standard assumptions, we prove that the methods are well-defined and that the sequences they generate converge to a projected solution of the quasi-equilibrium problem. Additionally, we prove that both methods attain an R-linear rate of convergence under the relatively strong monotonicity assumption. Furthermore, we perform numerical experiments on some test problems to illustrate the effectiveness of the proposed methods. The results obtained in this paper can be considered as the generalization and improvement of some existing works in the field of equilibrium and quasi-equilibrium problems.

A Variational Inverse Problem Framework for Multispectral Image Super-Resolution

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Abstract: Super-resolution of multispectral satellite imagery can be naturally formulated as an ill-posed inverse problem, where the recovery of high-resolution spatial information from degraded observations is inherently non-unique and sensitive to noise. In this work, we propose a variational inverse problem framework for multispectral image super-resolution that is grounded in optimization theory and motivated by physical image formation models commonly encountered in remote sensing.

The reconstruction task is posed as the minimization of an objective functional consisting of a data fidelity term derived from a linear degradation operator, coupled with regularization terms that encode prior structural information about the underlying multispectral image. In particular, spatial regularity is enforced through total variation–

based penalties, while spectral coherence across bands is preserved using sparsity-promoting constraints. Both convex and non-convex regularization regimes are considered, enabling a comparative analysis of stability, optimality conditions, and reconstruction behavior under different modeling assumptions.
To solve the resulting high-dimensional optimization problem efficiently, proximal gradient–based algorithms and alternating direction methods are employed, offering provable convergence guarantees under standard assumptions. Theoretical insights into the existence of minimizers and the influence of regularization parameters on solution quality are discussed, highlighting the trade-off between noise suppression and detail preservation. Numerical experiments on multispectral satellite imagery demonstrate that the proposed variational formulations yield reconstructions with improved spatial sharpness and spectral fidelity, while exhibiting enhanced robustness to noise and atmospheric perturbations when compared to purely data-driven approaches.
The proposed framework emphasizes interpretability, mathematical transparency, and algorithmic reliability, thereby providing a principled alternative to black-box learning methods for super-resolution in remote sensing applications.

Reliability Analysis of Energy Management Subsystem in a High Altitude Platform Station

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Abstract: 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.
The increasing need for faster data rates and better performance has prompted wireless network providers to consider energy management in High Altitude Platform Station (HAPS) over Internet of Things (IoT). Energy management is a basic requirement for solar-powered HAPS, which has not been paid attention in recent times. This HAPS architecture suffers from limited and un reliable energy management resources. Although there are many competent technologies working for the purpose of capacity enhancement and reliability of the Energy Management Subsystem (EMS), such as optimization of propulsion energy and energy optimization technologies, there is still room and need for further improvement. In this work, we introduce a three-level hierarchical model to evaluate the reliability characteristics of EMS in HAPS. Two different methods, Continuous-Time Markov Chains (CTMCs) and Reliability Block Diagrams (RBDs), are used to model this hierarchical model of EMS in HAPS. CTMC-based modeling is used to evaluate performance metrics, such as the re liability function and Mean Time To Failure (MTTF), at two different levels

by using k-out-of-n stochastic modeling technique. Further, the proposed k-out-of-n models for repairable and non-repairable batteries and solar cells are subject to an analytical investigation, and their validity is confirmed using discrete event simulation. The precision in estimating reliability and temporal attributes for diverse input data, employing important parameters, is attained through the widely recognized machine learning models.

Multi-Objective Redundancy Allocation Problem for Systems with Weighted k-out-of-n Subsystems Formed by Different Types of Multistate Components

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Abstract: The redundancy allocation problem (RAP) is considered as one of the important problems in reliability theory. In this paper, we consider a series system with several subsytems wherein each subsystem is a weighted k-out-of-n system formed by different types of multi-state components. The degradation of the performance level (i.e., the probability of changing from a given state i to the next state $(i-1)$) of a component of the system is modeled by the Markov process. Then, we study the multi-objective RAP problem for this system, i.e., we determine the optimum number of components of each type in each subsystem so that the maximum system reliability is achieved at minimum cost. Note that the given RAP problem is of NP-hard type and consequently, we use the controlled elitism non-dominated ranked genetic algorithm (CE-NRGA) to solve this problem. At the end, we illustrate the proposed methodology through a numerical example. Moreover, we discuss a case study to validate the proposed model.

Going Beyond Subsidies: Does Cap Setting under Cap-and-Trade Policy Encourage the Adoption of Green Products Across Scope 1, 2, and 3 Emissions, or does It Require an Additional Carbon Tax?

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Abstract: The rising concern over climate change has led governments across the globe to adopt various policy interventions, mostly subsidies, cap-and-trade regulations, and carbon taxation, to accelerate the transition from conventional products to environmentally sustainable alternatives. Despite widespread adoption, the evidence from several countries shows that subsidy only schemes are often inadequate to meet environmental goals. For instance, the UK's Green Home Grant underperformed significantly, France's heat pump market has slowed despite continued support, and Japan's solar industry witnessed a decline after an initial boom. These examples highlight the need for complementary or alternative policy measures beyond subsidies. In this study, we develop a supply chain framework comprising a manufacturing firm that produces both green and traditional non-green products, and two consumer segments: green consumers and ordinary consumers. The government acts as a regulatory body and implements three types of policy interventions: (i) ongoing subsidy policy, (ii) implements regulation via a cap-and-trade mechanism along with subsidy, and (iii) taxation in the form of carbon taxes on non-green products along with subsidy and cap and trade. We also classify the firm's emissions into Scope 1, Scope 2, and Scope 3 categories, distinguishing between controllable and uncontrollable emissions. Further, the firms are endogenous their decision on emission reduction through Scope 1, 2 and 3 corresponding to each policy orientation. Using a game-theoretic approach, we analyze how manufacturers determine their optimal emission-reduction strategies under different policies, and how such decisions influence consumer welfare and social welfare.

Ranking Feature Importance Objectives for Explainable Classification

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Abstract: Recent studies on explainable machine learning models often analyse feature importance after training, but this results in a model that does not capture feature dependencies and requires extra computational resources for explainability. We propose a method for training a supervised learning model through multi-objective optimisation that considers accuracy and feature importance in a unified framework. This method provides an explainable training procedure that consistently minimises the model's loss and maximises individual feature importance objectives, improving classification decision-making. We explore interpretable model training using many-objective and bi-

objective optimisation formulations. Choosing an interpretable framework from these pathways is challenging, so we propose outranking them by constructing a credibility index based on performance metrics. Our experiments on the UCI repository and medical image datasets show the benefits of capturing feature importance early, ensuring intrinsic explainability.

A Cost-Sensitive Loss for Imbalanced Classification: Benchmark Results and Unseen Validation

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Abstract: Remote Sensing Scene Classification has significant challenge of class imbalance. Despite this, only few research works focuses on cost-sensitive or algorithm-based solutions in the RS domain to address the class imbalance. There is still a significant research gap in loss function alternatives, specifically in RSSC, for handling class imbalance. Unlike Cross-entropy and Hinge Loss function, the proposed formulation integrates adaptive sample reweighting with margin-aware penalization for adaptive decision boundaries. We conduct a comprehensive evaluation on benchmark datasets and further validate the approach on unseen data to quantify robustness and transferability. Experimental results show consistent improvements in macro-level metrics, including macro-F1 and balanced accuracy, along with reduced misclassification among minority classes. Ablation studies, sensitivity to hyperparameters confirms the robustness of the loss function in imbalanced data.

Introduction to Indian Institute of Technology (BHU) Varanasi

The Indian Institute of Technology (Banaras Hindu University) Varanasi is one of India's premier institutions of higher education, combining a rich historical legacy with modern scientific excellence. The Institute completed 100 years of distinguished service in 2019 and continues to advance with renewed vigor, dedication, and a strong commitment to nation-building.

The Institute owes its origin to Bharat Ratna Mahamana Pandit Madan Mohan Malviya, the visionary founder of Banaras Hindu University (BHU), the first residential university of modern India. Recognizing the crucial role of technical education in shaping an independent and self-reliant nation, he initiated engineering education at BHU in 1919 with the establishment of Banaras Engineering College (BENCO). This was followed by the creation of the College of Technology (TECHNO) and the College of Mining & Metallurgy (MINMET). In 1968, these institutions were merged to form the Institute of Technology (IT-BHU), consolidating technical education under a unified framework.

Since 1972, IT-BHU admitted students through the Joint Entrance Examination (JEE) conducted by the IITs, reflecting its national standing and academic rigor. Consistently ranked among the leading engineering institutions in the country, IT-BHU earned a strong reputation for excellence in teaching, research, and innovation.

A landmark transformation occurred on June 29, 2012, when IT-BHU was converted into the Indian Institute of Technology (BHU) Varanasi by an Act of Parliament. Following its elevation to IIT status, the Institute rapidly aligned its academic structure, governance, and research practices with the high standards of the IIT system.

Today, IIT (BHU) Varanasi offers undergraduate, postgraduate, dual-degree, and doctoral programs across diverse disciplines in engineering, science, and interdisciplinary research. With state-of-the-art facilities, a vibrant academic environment, and strong industry and global collaborations, the Institute continues to nurture talent, generate impactful research, and contribute significantly to technological advancement and societal development.

Rooted in tradition yet driven by innovation, IIT (BHU) Varanasi stands as a symbol of excellence, dedicated to creating knowledge and shaping leaders for the future.

Introduction to Department of Mathematical Sciences
Indian Institute of Technology (BHU) Varanasi

The Department of Mathematical Sciences was established as a section to assist the engineering departments of the institute, which, in the true sense, pioneered engineering education in the Indian nation. It soon acquired the status of a full-fledged department in 1985. It did not stagnate thereafter. Over the years, it underwent several transformations in tune with global developments, evolved with the changing world, and continually redefined itself. Finally, in 2013, following the transformation of the erstwhile Institute of Technology into the Indian Institute of Technology, it was reconstituted as the "Department of Mathematical Sciences" to serve humanity with a broader perspective - not only as an interface among various disciplines but also as a hub for generating fundamental knowledge. The Upanishads also proclaim, "Charaiveti," meaning "Keep moving."

Undoubtedly, mathematics in its purest form has been the department's prime concern, and its advancement lies at the core of its vision. Mathematics is often described as the queen of the sciences. Indeed, it is the nectar that assumes the flavour of the science it describes; it is the light that illuminates according to the colour upon which it falls; and it is the elixir that has sustained the laws of nature since time immemorial and will continue to do so through ages yet to be conceived.

The department emphasizes research in areas such as analysis, algebra, geometry, mathematical modelling, probability, statistics and optimization, to name a few. However, its distinguishing feature lies in relating the intrinsic beauty of mathematics to the advancement of science, strengthening knowledge with zeal, and ultimately serving humankind. Whether in fluid dynamics, biomechanics, fracture mechanics, digital image processing, generalized thermo-elasticity, heat and mass transfer, cosmology, cryptology, or many other applied fields, the department's contributions have been substantial, as reflected in numerous research papers published in reputed international journals over the past few decades. Computing is another strong pillar of the department. It encompasses several emerging dimensions of research and further facilitates the simulation of mathematical models developed for interdisciplinary areas.

The department runs an B.Tech. program in Mathematics & Computing. This is one of the most sought-after courses offered by the institute. Some of the highest annual salary packages are offered to graduates of this program, which strongly indicates its popularity and relevance for industrial growth in general, and for the software industry in particular, under present circumstances. Although the program is just over a decade old, several graduates of the department have secured admission to MS and Ph.D. programs at some of the world's top universities.

Tourist Attractions Introduction

Varanasi, also known as Kashi or Banaras, is one of the world's oldest continuously inhabited cities. Situated on the banks of the sacred River Ganga, it is the spiritual capital of India and a vibrant center of religion, philosophy, music, art, and culture.

Kashi Vishwanath Temple

The Kashi Vishwanath Temple is one of the most sacred temples dedicated to Lord Shiva and houses one of the twelve Jyotirlingas. It attracts millions of devotees every year. The temple complex has been beautifully redeveloped under the Kashi Vishwanath Corridor project, providing improved access from the ghats to the temple. The temple symbolizes the eternal spiritual essence of Varanasi. Devotees believe that a visit here grants liberation (moksha). The atmosphere during festivals like Mahashivaratri and Shravan month is especially divine.

Dashashwamedh Ghat and Assi Ghat

Dashashwamedh Ghat is the most famous and lively ghat in Varanasi. According to legend, Lord Brahma performed ten Ashwamedha Yajnas here. The highlight of this ghat is the grand **Ganga Aarti**, performed every evening with rhythmic chants, lamps, conch shells, and devotional music. Thousands of visitors gather daily to witness this mesmerizing ritual. A boat ride during the aarti offers a breathtaking view of the illuminated ghats. Assi Ghat is located at the southern end of the city where the Assi River meets the Ganga. It is known for its peaceful environment and is popular among students, locals, and tourists. The early morning "Subah-e-Banaras" program includes yoga sessions, devotional music, and cultural performances. Sunrise boat rides from Assi Ghat provide one of the most beautiful panoramic views of Varanasi's ghats.

Sankat Mochan Hanuman Temple

This temple is dedicated to Lord Hanuman and is believed to relieve devotees from troubles ("Sankat"). It was established by the saint Tulsidas. The temple is especially crowded on Tuesdays and Saturdays. It is also known for the annual classical music and dance festival, which attracts renowned artists from across India.

Tulsi Manas Temple

Built in white marble, Tulsi Manas Temple marks the place where Goswami Tulsidas composed the Ramcharitmanas. Verses from the Ramcharitmanas are inscribed on the temple walls. The temple is peaceful and artistically designed, depicting scenes from the Ramayana through beautiful carvings and displays.

Ramnagar Fort

Located across the Ganga, Ramnagar Fort was built in the 18th century by the Kashi Naresh (King of Varanasi). The fort houses a museum displaying vintage cars, royal costumes, manuscripts, and historical artifacts. The fort is especially famous for hosting the traditional Ramleela during Dussehra.

Sarnath

Sarnath is one of the most important Buddhist pilgrimage sites in the world. The most prominent monument here is the **Dhamek Stupa**, which marks the exact spot where Lord Buddha delivered his first sermon after attaining enlightenment. The historic **Ashoka Pillar**, erected by Emperor Ashoka in the 3rd century BCE, once stood here, and its Lion Capital is now the National Emblem of India. The **Mulagandha Kuti Vihar** is a modern Buddhist temple known for its beautiful frescoes depicting scenes from Buddha's life, while the **Chaukhandi Stupa** commemorates the meeting of Buddha with the five ascetics who became his first disciples. The **Sarnath Archaeological Museum** preserves invaluable artifacts, including the original Lion Capital and ancient Buddhist sculptures. In addition, Sarnath is home to several international temples such as the **Thai Temple, Tibetan Temple, and Japanese Temple (Nichigai Suzan Horinji Temple)**, each reflecting distinctive architectural styles and spiritual traditions. The sacred **Bodhi Tree**, grown from a sapling of the original tree at Bodh Gaya, further enhances the serene and meditative atmosphere of this historic and spiritual destination.

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