ABSTRACTS BOOK

icame@balikesir.edu.tr
https://icame.balikesir.edu.tr



ICAMΣ'26

The 4th International Conference on Applied Mathematics in Engineering

2-4 September 2026, Cunda/Ayvalık - Türkiye

ICAMΣ'26

The 4th International Conference on Applied Mathematics in Engineering

2–4 September 2026, Cunda, Balıkesir, Türkiye

Abstracts Book

September 2026, Balıkesir

eISBN: 978-625-5540-34-8

Cite articles as follows:

Author surname, Initial., Author surname, Initial. (2026). Paper Title. The 4th International Conference on Applied Mathematics in Engineering (ICAME'26), Cunda, Türkiye, 2–4 September.

Preface

We are pleased to welcome all participants to "The 4th International Conference on Applied Mathematics in Engineering (ICAME'26)," taking place between 2–4 September 2026 in Cunda, Ayvalık, Balıkesir, Türkiye.

This conference offers an ideal academic platform for researchers to present the latest research and emerging findings in optimization and applied mathematics across engineering, physics, chemistry, biology, energy, and statistics. It also provides a valuable opportunity to discuss advances in artificial intelligence and its impact on engineering and real-life challenges.

The conference focuses on contemporary applied mathematical problems worldwide, including fractional calculus and its real-life applications, differential equations, operational research, mathematical modeling in engineering, artificial intelligence and machine learning applications, physics-informed neural networks, optimization and control in engineering, non-linear dynamical systems and chaos, and stochastic modeling of natural phenomena. Alongside 7 plenary and invited talks and 13 special sessions, 133 oral presentations will be delivered to an international audience, bringing together 259 authors from 34 countries (*i.e. Albania, Algeria, Brazil, Bulgaria, China, Egypt, France, Greece, Hungary, India, Iran, Iraq, Italy, Japan, Jordan, Kazakhstan, Kosovo, Kuwait, Lebanon, Morocco, Nigeria, Oman, Pakistan, Poland, Saudi Arabia, Singapore, South Korea, Spain, Türkiye, Ukraine, United Arab Emirates, United Kingdom, United States, and Uzbekistan*).

ICAME'26 represents a significant milestone in our ongoing efforts to foster and advance international cooperation. In this scope, on behalf of the organising committee of the conference, we would particularly like to thank our plenary speakers Hüseyin Şeker *(University of Sharjah, United Arab Emirates & University of Birmingham, United Kingdom)*, Young-Im Cho *(Gachon University, Republic of Korea)*, Jordan Hristov *(University of Chemical Technology and Metallurgy, Bulgaria)*, Dumitru Baleanu *(Lebanese American University, Lebanon)*, Maíra Aguiar *(Basque Center for Applied Mathematics – BCAM, Spain)*, Gerhard-Wilhelm Weber *(Poznan University of Technology, Poland)* and Praveen Agarwal *(Anand International College of Engineering, Jaipur, India)*, as well as the organisers of the special sessions and the members of the international scientific committee for their contributions and support.

We extend our best wishes to all participants, hoping you leave with valuable insights, enhanced ideas, and newly formed or strengthened scientific networks. Wishing you an enjoyable and memorable conference.

On behalf of the organising committee,

Chairs

Dumitru Baleanu	*Ramazan Yaman*	*Jordan Hristov*	*Necati Ozdemir*
Lebanese American University, Lebanon	*Balikesir University, Türkiye*	*Univ. of Chemical Tech. and Metallurgy, Bulgaria*	*Balikesir University, Türkiye*

Conference Committee

Chairs

Dumitru Baleanu, Lebanese American University, Lebanon
Ramazan Yaman, Balikesir University, Turkiye
Jordan Hristov, Univ. of Chemical Tech. and Metallurgy, Bulgaria
Necati Ozdemir, Balikesir University, Turkiye

Organising Committee

Ramazan Yaman, Balikesir University, Turkiye
Dumitru Baleanu, Lebanese American University, Lebanon
Necati Ozdemir, Balikesir University, Turkiye
Firat Evirgen, Balikesir University, Turkiye
Gerhard Wilhelm Weber, Poznan University of Technology, Poland
Ibrahim Kucukkoc, Balikesir University, Turkiye
Burcu Gurbuz, Johannes Gutenberg-University Mainz, Germany
Mehmet Yavuz, Necmettin Erbakan University, Turkiye
Yeliz Karaca, University of Massachusetts, USA

Program Committee

Ramazan Yaman, Balikesir University, Türkiye
Necati Ozdemir, Balikesir University, Türkiye
Firat Evirgen, Balikesir University, Türkiye
Ibrahim Kucukkoc, Balikesir University, Türkiye

International Scientific Committee

Abdeljawad, T., Saudi Arabia
Agarwal, P., India
Ahmad, I., Saudi Arabia
Akin, O., Turkiye
Area, I., Spain
Atanackovic, T., Serbia
Atangana, A., South Africa
Ayaz, F., Turkiye
Bagirov, A., Australia
Baskonus, H.M., Turkiye
Baleanu, D., Lebanon
Cho, Y.I., S. Korea
Caputo, M., Italy
Cattani, C., Italy
Dassios, I., Ireland
Debbouche, A., Algeria
Defterli, O., Turkiye
El-Khazali, R., United Arab Emirates
El-Sayed, A., Egypt
Erturk, V.S., Turkiye
Golmankhaneh, A.K., Iran
Gulsu, M., Turkiye
Gurbuz, B., Germany
Holm, S., Norway
Hristov, J., Bulgaria
Jafari, H., South Africa
Jarad, F., Turkiye
Kaya, D., Turkiye
Kazmi, I., Pakistan
Keedwell, E.C., UK
Klimek, M. Poland
Konuralp, A., Turkiye
Kumar, D., India
Leblebicioglu, K., Turkiye
Li, C.P.,China
Liu, F., Australia
Luo, A.C.J, USA
Magin, R. L., USA
Marin, M., Romania
Mandzuka, S., Crotia
Markowski, K.A., Poland
Merdan, H., Turkiye
Momani, S., Jordan
Nigmatullin, R. R., Russia
Ozcan, E., UK
Peron, M., France

Pinto, C.M., Portugal
Podlubny, I., Slovakia
Povstenko, Y., Poland
Prodanov, D., Belgium
Sari, M., Turkiye
Seker, H., UAE & UK
Shams, M., Turkiye
Sing, J., India
Sproessig, W., Germany
Sulaiman, S., Malaysia
Tabucanon, M.T., Thailand
Tarasov, V.E., Russia
Thuto, M.V., Botswana
Torres, D.F.M., Portugal
Townley, S., UK
Trujillo, J.J., Spain
Weber, G.W., Poland
Wu, G.C., China
Yang, X.J., China
Zhang, D.Z., UK

Local Organizing Committee

Akdemir, M., Turkiye
Calgan, H., Turkiye
Demir, T., Turkiye
Demirtas, M., Turkiye
Gökkaya, H., Turkiye
Gucu, S, Turkiye
Inan, D., Turkiye
Karaoglan, A.D., Turkiye
Yaman, G., Turkiye
Yildirim, H.H., Turkiye
Yilmaz, T., Turkiye

Conference Program

ICAME'26 - CONFERENCE PROGRAMME OUTLINE* (https://icame.balikesir.edu.tr)					
Day 1: Wednesday, 2 September 2026		**Day 2: Thursday, 3 September 2026**		**Day 3: Friday, 4 September 2026**	
09:00-10:00	**Registration**	09:00-09:30	**Registration**	09:00-09:30	**Registration**
10:00-10:30	**Opening Ceremony (Hall-1)** *Conference Chairs*	09:30-10:10	**Plenary Lecture-4 (Hall-1)** **Dumitru Baleanu**	09:00-10:40	**Parallel Sessions - 6** *09:00-09:20* *09:20-09:40* *09:40-10:00* *10:00-10:20* *10:20-10:40*
10:30-11:10	**Plenary Lecture-1 (Hall-1)** **Hüseyin Şeker**	*10:15-10:35*	*Coffee Break*		
11:15-11:35	*Coffee Break*	10:35-12:15	**Parallel Sessions - 4** *10:35-10:55* *10:55-11:15* *11:15-11:35* *11:35-11:55* *11:55-12:15*	10:45-11:25	**Plenary Lecture-5 (Hall-1)** **Praveen Agarwal** ***[online]***
11:35-12:15	**Plenary Lecture-2 (Hall-1)** **Young Im Cho** ***[online]***			11:30-11:50	**Closing Ceremony (Hall-1)**
12:15-13:25	***LUNCH***	*12:15-13:25*	***LUNCH***	12:00-...	**Social Tour** **(Ayvalık-Cunda)** **Tour plan will be announced with a certain timeline soon.**
13:30-15:10	**Parallel Sessions - 1** *13:30-13:50* *13:50-14:10* *14:10-14:30* *14:30-14:50* *14:50-15:10*	13:35-14:15	**Plenary Lecture-5 (Hall-1)** **Maíra Aguiar [online]**		
		14:25-15:05	**Plenary Lecture-6 (Hall-1)** **Gerhard Wilhelm Weber [online]**		
15:15-15:55	**Plenary Lecture-3 (Hall-1)** **Jordan Hristov**	*15:05-15:25*	*Coffee Break*		
15:55-16:15	*Coffee Break*	15:30-17:10	**Parallel Sessions - 5** *15:30-15:50* *15:50-16:10* *16:10-16:30* *16:30-16:50* *16:50-17:10*		
16:15-17:35	**Parallel Sessions - 2** 16:15-16:35 16:35-16:55 16:55-17:15 17:15-17:35				
17:35-17:50	*Coffee Break*	*17:10-17:30*	*Coffee Break*		
17:50-19:30	**Parallel Sessions - 3** 17:50-18:10 18:10-18:30 18:30-18:50 18:50-19:10 *19:10-19:30*	17:30-18:15	**Round-table Discussion** *(Hall-1)*		
19:30	***DINNER***	*19:30*	***DINNER***		

*This is the general outline of the conference program. The detailed program can be downloaded from the conference website.

NOTE: All times in GMT+3 (click here to check local time)

ICAME'26 - CONFERENCE PROGRAM (AUTHORS)
The 4th International Conference on Applied Mathematics in Engineering
2-4 September 2026, Ayvalık (Cunda)-Balıkesir, Türkiye
[Updated: 30th August 2026 - 12:00 Istanbul Time]

Day-1
Wednesday, 2nd September 2026

Day-1
Wednesday, 2nd September 2026

09:00-10:00		**Registration**					
Opening	**10:00-10:30 (All Times GMT+3)**	**Opening Ceremony (Hall-1)**					
		Speakers:	***Conference Chairs***				
		Link:	https://us06web.zoom.us/j/2935213395?pwd=cV5gRbMTisjaeL74UXijEFSkxWG1EU.1				
Plenary	**10:30-11:10**	**Plenary Lecture-1 (Hall-1)**	**The Power of Data and The Things It Empowers**				
		Speaker:	***Hüseyin Şeker***				
		Chair:	*Zakia Hammouch*				
		Link:	https://us06web.zoom.us/j/2935213395?pwd=cV5gRbMTisjaeL74UXijEFSkxWG1EU.1				
11:15-11:35		*Coffee Break*					
Plenary	**11:35-12:15**	**Plenary Lecture-2 (Hall-1)**	**An Explainable Multimodal AI Framework for Proactive Urban Risk Intelligence and Decision Support in Smart Cities**				
		Speaker:	***Young Im Cho - Online***				
		Chair:	*Ramazan Yaman*				
		Link:	https://us06web.zoom.us/j/2935213395?pwd=cV5gRbMTisjaeL74UXijEFSkxWG1EU.1				
12:15-13:25		***LUNCH***					
Parallel Sessions-1		**Room-1 (Hall-1)**	**Room-2 (Hall-2)**	**Room-3 (Online)**	**Room-4 (Online)**	**Room-5 (Online)**	
	Session:	**Nonlinear Dynamics**	**Operations Research**	**AI & Computational Methods**	**Energy Systems & OR**	**Neural Networks**	
	Chair:	**Münevver Tezer-Sezgin**	**Ilker Kucukoglu**	**Gabriel Torregrosa-Cortés**	**Melike Sultan Karasu Asnaz**	**Süleyman Cengizci**	
	Link:	Click here	Click here	Click here	Click here	Click here	
	13:30	34 - André Lopes	162 - Ilker Kucukoglu	180 - Gabriel Torregrosa-Cortés	153 - Ismail Caner	7 - Süleyman Cengizci	
	13:50	48 - Münevver Tezer-Sezgin	112 - Helin Su Acar	8 - Ali Berkol	174 - Sadettin Durmuş Talipoğlu	214 - Mehmet Yavuz	
	14:10	67 - Pelin Şenel	119 - Seyma Mercan	21 - Mohammed Alabdullah	158 - Melike Sultan Karasu Asnaz	42 - Fatma Nur Kaya Saglam	
	14:30	85 - F. Sidre Oğlakkaya	32 - Oktay Yılmaz	83 - Wajdi Ben Saad	80 - Semiha Erkovan	53 - Hamid Orhun Tur	
	14:50	106 - Canan Bozkaya		156 - Abdullah Usame Gündeşli	166 - Mehmet Çeçen	64 - Gülden Mülayim	
Plenary	***15:15-15:55***	**Plenary Lecture-3 (Hall-1)**	**Sigmoids based on Mittag-Leffler functions and known memory kernels**				
		Speaker:	***Jordan Hristov***				
		Chair:	*Dumitru Baleanu*				
		Link:	https://us06web.zoom.us/j/2935213395?pwd=cV5gRbMTisjaeL74UXijEFSkxWG1EU.1				
15:55-16:15		*Coffee Break*					
Parallel Sessions-2		**Room-1 (Hall-1)**	**Room-2 (Hall-2)**	**Room-3 (Online)**	**Room-4 (Online)**	**Room-5 (Online)**	
	Session:	**Nonlinear Dynamics**	**AI & Computational Methods**	**Math/Analysis**	**Mathematical Modelling**	**Modelling & Optim in Eng**	
	Chair:	**Fatma Tokmak Fen**	**Yeliz Karaca**	**Yassine Sabbar**	**Firat Evirgen**	**Ramazan Yaman**	
	Link:	Click here	Click here	Click here	Click here	Click here	
	16:15	20 - Esma Ulutaş	55 - Özge Çelik	40 - Seza Dinibütün	145 - Oluwaseun O. Okundalaye	122 - Gökhan Karcıoğlu	
	16:35	149 - Ruşen Kaya	13 - Tuğba Aydemir	139 - Esma Canhasi Kasemi	201 - Halime Gökkaya	94 - Zeynep Nur Köstepen	
	16:55	177 - Mehmet Onur Fen	56 - Seda Ermiş	120 - Ebru Açıkgöz	191 - Longjun Zhan	124 - Gülşen Yaman	
	17:15	175 - Fatma Tokmak Fen	160 - Aykut Sen	38 - Furkan Gümüş	2 - Taha Yilmaz	207 - Fatma Selen Madenoğlu	
17:35-17:50		*Coffee Break*					
Parallel Sessions-3		**Room-1 (Hall-1)**	**Room-2 (Hall-2)**	**Room-3 (Online)**	**Room-4 (Online)**	**Room-5 (Online)**	
	Session:	**Mathematical Modelling**	**AI & Computational Methods**	**Nonlinear Dynamics**	**MCDM**	**Neural Networks**	
	Chair:	**Zakia Hammouch**	**İsmail Naci Cangul**	**Selçuk Han Aydın**	**Cansu Aksu**	**Mehmet Yavuz**	
	Link:	Click here	Click here	Click here	Click here	Click here	
	17:50	125 - Sultan Sütlü	60 - Derya Altıntan	50 - Selçuk Han Aydın	108 - Cansu Aksu	215 - Mehmet Yavuz	
	18:10	151 - Ahmet Çoban	205 - Ismail Naci Cangul	52 - Shokoufeh Ghezeljeh	121 - Meryem Abdullahaljouma	90 - Harun Selvitopi	
	18:30	45 - Demet Özdek	87 - Esra Çelik	58 - Ayşe Nur Altunkaya	35 - Çağrı Latifoğlu	186 - Upasnaben D Vala	
	18:50	79 - Sumran Gücü	54 - Musa Sina Ertuğrul	140 - Kerem Uğurlu	91 - Ritu Bhuyan	143 - Vladyslav Cherkashyn	
	19:10					146 - Oluwaseun O. Okundalaye	
19:30		***DINNER***					

Day-2
Thursday, 3rd September 2026

Day-2
Thursday, 3rd September 2026

09:00-09:30		**Registration**					
Plenary	**09:30-10:10**	**Plenary Lecture-4 (Hall-1)**	**On Modified Fractional Dynamics with Mittag-Leffler Kernel: Theory and Applications**				
		Speaker:	***Dumitru Baleanu***				
		Chair:	*Zakia Hammouch*				
		Link:	https://us06web.zoom.us/j/2935213395?pwd=cV5gRbMTisjaeL74UXijEFSkxWG1EU.1				
10:15-10:35		*Coffee Break*					
Parallel Sessions-4		**Room-1 (Hall-1)**	**Room-2 (Hall-2)**	**Room-3 (Online)**	**Room-4 (Online)**	**Room-5 (Online)**	
	Session:	**Fractional Calculus**	**Operations Research**	**Modelling & Optim in Eng**	**AI & Computational Methods**	**MCDM**	
	Chair:	**Dumitru Baleanu**	**Ibrahim Kucukkoc**	**Cihan Bayındır**	**Hasan Hüseyin Yıldırım**	**Ramazan Yaman**	
	Link:	Click here	Click here	Click here	Click here	Click here	
	10:35	75 - Dimiter Prodanov	170 - Melissa Bilge Karadere	203 - Noumedia Ouarab	161 - Hasan Hüseyin Yıldırım	173 - Recep Duranay	
	10:55	216 - Zakia Hammouch	29 - Oktay Yilmaz	206 - Ioannis D. Sfikas	152 - Melike Sultan Karasu Asnaz	147 - Elif Ünaldı	
	11:15	182 - Yeliz Karaca	95 - Elif Aydan Bike	126 - Mehmet Ali Kaygusuz	157 - Burak Aşkın	148 - Eszter Kiss	
	11:35	109 - Taylan Demir	97 - Didem Eylenen	41 - Sara Taheri	82 - Safaa Kahil	138 - Ece Nur Polat	
	11:55	169 - Ahmad Faraz Razi	107 - Berkin Yeginoğlu	181 - Ümit Çalışır	187 - İrem Köksaldı	134 - Samet Kürşat Başol	
12:15-13:25		***LUNCH***					
Invited Speaker	**13:35-14:15**	**Plenary Lecture-5 (Hall-1)**	**Modeling Dengue Dynamics: Unraveling the Impact of Homologous Reinfections**				
		Speaker:	***Maira Aguiar- Online***				
		Chairs:	*Burcu Gürbüz & Necati Ozdemir*				
		Link:	https://us06web.zoom.us/j/2935213395?pwd=cV5gRbMTisjaeL74UXijEFSkxWG1EU.1				
Invited Speaker	**14:25-15:05**	**Plenary Lecture-6 (Hall-1)**	**Optimal management of defined contribution pension funds under the effect of inflation, mortality and uncertainty**				
		Speaker:	***Gerhard-Wilhelm Weber -Online***				
		Chairs:	*Fırat Evirgen & Ramazan Yaman*				
		Link:	https://us06web.zoom.us/j/2935213395?pwd=cV5gRbMTisjaeL74UXijEFSkxWG1EU.1				
15:05-15:25		*Coffee Break*					
Parallel Sessions-5		**Room-1 (Hall-1)**	**Room-2 (Hall-2)**	**Room-3 (Online)**	**Room-4 (Online)**	**Room-5 (Online)**	
	Session:	**Math/Analysis**	**Modelling & Optim in Eng**	**Mech & Comp Methods**	**Routing & Scheduling**	**Mathematical Modelling**	
	Chair:	**Yeliz Mert Kantar**	**Yunus Eroğlu**	**Rommel Regis**	**Anett Rácz**	**Waleed Adel**	
	Link:	Click here	Click here	Click here	Click here	Click here	
	15:30	188 - Yeliz Mert Kantar	154 - Yunus Eroğlu	168 - Rommel Regis	141 - Anett Rácz	66 - Keiko Arase	
	15:50	16 - Neriman Şolt	37 - İlknur Tükenmez	133 - Sulaiman Mohammed Ibrahim	72 - Pınar Yunusoğlu	144 - Waleed Adel	
	16:10	189 - İlhan Usta	86 - Fatma Neşe Özen	28 - Nejat Tukenmez	164 - Miraç Huzeyfe Güner	132 - Gökçe Özaltun Şimşek	
	16:30	159 - Elif Güner	116 - Ulviye Savas	165 - Munarbek Aidaraliev	183 - Kartal Aydınlı	129 - Neriman Kartal	
	16:50	167 - Gözde Karapelit		26 - Ekin Oktay	192 - Sena Şaylıg	185 - Ashraf Adnan Thirthar	
	17:10						
17:10-17:30		*Coffee Break*					
Round-table	**17:30-18:15**	**Round-table Discussion (Hall-1)**					
		Link:	https://us06web.zoom.us/j/2935213395?pwd=cV5gRbMTisjaeL74UXijEFSkxWG1EU.1				
19:30		***DINNER***					

Day-3
Friday, 4th September 2026

Day-3
Friday, 4th September 2026

09:00-09:30		**Registration**				
Parallel Sessions-6		**Room-1 (Hall-1)**	**Room-2 (Hall-2)**	**Room-3 (Online)**	**Room-4 (Online)**	
	Session:	**Math/Analysis**	**Modelling & Optim in Eng**	**Eng & Applied Math**	**Computer Vision / AI**	
	Chair:	**Metin Demirtas**	**Sevdanur Genç**	**Hidekazu Yoshioka**	**Yassine Sabbar**	
	Link:	Click here	Click here	Click here	Click here	
	09:00	51 - Mohd Alam	178 - Sevdanur Genç	63 - Hidekazu Yoshioka	65 - Nigorakhon Nasimova	
	09:20	117 - Zühra Güneş	155 - Furkan Keskin	47 - Arda Yalcinkaya	135 - Yassine Sabbar	
	09:40	74 - Melike Kaysal	163 - Muhammed Berat Altınok	123 - Elif Tarakçı	131 - Mehmet Ali Kaygusuz	
	10:00	136 - Nazlı Karataş Aygün	172 - Ramazan Altay	22 - Sara Taheri	202 - Lada Asankulova	
	10:20	113 - Haris Calgan		179 - Halil Sinoplugil	217 - Artan Alidema	
Invited Speaker	**10:45-11:25**	**Plenary Lecture-7 (Hall-1)**	**A study of integral formulas involving generalized special functions**			
		Speaker:	***Praveen Agarwal - Online***			
		Chair:	*Jordan Hristov*			
		Link:	https://us06web.zoom.us/j/2935213395?pwd=cV5gRbMTisjaeL74UXijEFSkxWG1EU.1			
Closing	**11:30-11:50**	**Closing Ceremony (Hall-1)**				
		Link:	https://us06web.zoom.us/j/2935213395?pwd=cV5gRbMTisjaeL74UXijEFSkxWG1EU.1			
12:00 - ...		***Social Tour (Ayvalik-Cunda)*** ***Tour plan will be announced with a certain timeline soon.***				

Zoom Connection Links

Room-1 (Hall-1 Onsite):
https://us06web.zoom.us/j/2935213395?pwd=cV5gRbMTisjaeL74UXijEFSkxWG1EU.1

Room-2 (Hall-2 Onsite):
https://us06web.zoom.us/j/3129610165?pwd=H3NHPbY4azbafuctHirks6dYPwBqMn.1

Room-3 (Online):
https://us06web.zoom.us/j/5565200022?pwd=NkwrSGtwWEg2dXNxODBTVHEzNDVZdz09

Room-4 (Online):
https://us06web.zoom.us/j/5892213649?pwd=TsMekY29dzCeYWUijEKNwa3QAZlo2R.1

Room-5 (Online):
https://us06web.zoom.us/j/7421593900?pwd=xmvtkcav1rno5eCd6G8EdBiOHDYkdN.1

About Cunda

Cunda is a touristic island in Ayvalik, which is a municipality and district of Balikesir Province, Turkiye. Its area is 305 km2, and its population is 74,030 (2022). It is a seaside town on the northwestern Aegean coast of Turkiye. The town centre is connected to Cunda Island by a causeway and is surrounded by the archipelago of Ayvalık Islands.

The ruins of three important ancient cities lie within a short drive of Ayvalık: Assos and Troy are to the north, while Pergamon (modern Bergama) is to the east. Mount Ida (Turkish: Kaz Dağı), which played an important role in ancient Greek mythology and folk tales, is also near Ayvalık (to the north) and can be seen from many points in and around the town centre.

The Gulf of Edremit and the coastal resort towns of Dikili (near ancient Atarneus) and Foça (ancient Phocaea) are also within driving distance for daily excursions.



Plenary Speakers

Young-Im Cho

Department of IT Convergence Engineering, Gachon University, Republic of Korea,
Email: yicho@gachon.ac.kr



An Explainable Multimodal AI Framework for Proactive Urban Risk Intelligence and Decision Support in Smart Cities

Urban environments are increasingly exposed to complex and interdependent risks, including air pollution, extreme weather, and infrastructure failures, which generate heterogeneous and fragmented data across multiple city systems. Conventional single-source or isolated models are therefore insufficient for reliable risk assessment.

This paper proposes an explainable multimodal AI framework for proactive urban risk intelligence in smart cities by integrating environmental, mobility, infrastructure, and energy data. The framework performs spatiotemporal data fusion and multi-horizon hazard and risk forecasting using a Temporal Fusion Transformer (TFT), while SHAP-based explainability identifies key drivers and enhances transparency of model predictions.

Beyond prediction, the framework incorporates a constraint-aware decision module that translates risk forecasts into actionable operational recommendations. Experimental results demonstrate that the proposed approach provides accurate, interpretable, and practically useful insights, enabling the transition from reactive monitoring to proactive and explainable urban risk management.

Dumitru Baleanu

Lebanese American University, Lebanon
Institute of Space Sciences, Magurele-Bucharest, Romania, Email: dumitru.baleanu@lau.edu.lb



On Modified Fractional Dynamics with Mittag-Leffler Kernel: Theory and Applications

Fractional calculus represents an extension of meaning, thus several related operators were introduced during the last 330 years. In this presentation, I will discuss the advantages of using the newly introduced singular modified fractional operator with Mittag-Leffler kernel (MABC). As we know dealing with nonsingular kernels is not an easy task due to their restrictions at origin. I suggest alternative extensions of the fractional operator involving the Mittag-Leffler kernel which admits an integrable singular kernel at the origin. Some illustrative examples will be presented.

Huseyin Seker

University of Sharjah, UAE & University of Birmingham, UK, Email: hseker@sharjah.ac.ae



The Power of Data and The Things It Empowers

Data has become the driving force of transformation across every sector of modern life. From intelligent infrastructure and connected industries to predictive healthcare and sustainable cities, data no longer just describes the world—it shapes it. This keynote explores how data fuels innovation, decision-making, and resilience in an increasingly digital and interconnected environment. It examines the new forms of intelligence that emerge when data is combined with technologies such as artificial intelligence, the Internet of Things, and advanced analytics. Through real-world examples, it highlights how organizations can harness data responsibly to create value, enhance efficiency, and enable human-centered progress. The talk also addresses the ethical, governance, and sovereignty challenges that come with this growing power, emphasising the importance of trust, transparency, and inclusion in data-driven ecosystems. Participants will leave with a deeper understanding of how data empowers not only technologies but also societies—and how its thoughtful use can drive competitiveness, innovation, and shared prosperity in the digital age.

Maíra Aguiar

Basque Center for Applied Mathematics (BCAM) in Bilbao, Spain, Email: maguiar@bcamath.org



Modeling Dengue Dynamics: Unraveling the Impact of Homologous Reinfections

Dengue dynamics are shaped by complex immune interactions among co-circulating serotypes, including temporary cross-immunity and antibody-dependent enhancement during heterologous reinfections. While most models assume lifelong immunity against the infecting serotype, recent evidence suggests that homologous reinfections can occur, although they are often mild or asymptomatic.

We present a modeling framework that links antibody-mediated immune dynamics with dengue transmission, incorporating both homologous and heterologous reinfections. The model reproduces key patterns of viral load and antibody production observed in primary and secondary infections and forms the basis for a multi-strain population model including temporary cross-immunity, ADE, and reinfection pathways.

We use this framework to assess how rare homologous reinfections may influence dengue persistence, outbreak dynamics, and transmission in endemic settings. We also discuss implications for temperate regions such as Europe, where local outbreaks are increasingly linked to viremic imported cases and established Aedes vectors.

Gerhard-Wilhelm Weber

Poznan University of Technology, Poland, Email: gerhard.weber@put.poznan.pl



Optimal management of defined contribution pension funds under the effect of inflation, mortality and uncertainty

The aim of the present project is to provide a novel, unified framework for the study of the problem of the optimal management of defined contribution pension funds under the effects of risk and model uncertainty. More precisely, we consider a fund manager who is endowed with some initial wealth stemming from pooled contributions of the fund members and his role is to optimally distribute this wealth, among several financial assets, in order for the fund to achieve some desired goal at the end of the trading horizon and to effectively mitigate any unnecessary risks. Furthermore, given the special design and the long-term structure of pension fund schemes, the effects of important external stochastic (market and demographic) factors, such as human mortality, interest rates and inflation, as well as model uncertainty, must be included in the decision-making process. By employing a mixture of robust control theory and dynamic programming techniques, we are able to provide: (i) the optimal investment decisions of the fund manager in closed-form, and a (ii) comprehensive numerical study (using real-world data and a novel machine-learning inspired approach) of the qualitative features of the problem at hand, that provides valuable insights on how the suggested pension fund management approach can be effectively applied in practice.

Reference: I. Baltas, L. Dopierala, K. Kolodziejczyk, M. Szczepański, G.-W. Weber (presenter), A. N. Yannacopoulos (2022). Optimal management of defined contribution pension funds under the effect of inflation, mortality and uncertainty, European Journal of Operational Research, 298(3), 1162-1174.

Praveen Agarwal

Anand International College of Engineering, Jaipur, India, Email: goyal.praveen2011@gmail.com



A study of integral formulas involving generalized special functions

A remarkably large number of integrals whose integrands are associated, in particular, with a variety of special functions, for example, the hypergeometric and Mittag–Leffler type functions have been recorded. Here we aim at presenting certain (presumably) new and (potentially) useful integral formulas whose integrands are involved in the special functions. Some interesting special cases of our main results are also considered.

Jordan Hristov

University of Chemical Technology and Metallurgy, Bulgaria, Email: jyh@uctm.edu



Sigmoids based on Mittag-Leffler functions and known memory kernels

Progress has been made in developing sigmoids derived from the Mittag-Leffler function. Generally, the Mittag-Leffler functions with one and two parameters, along with the Atangana-Baleanu formulation, are used to replace the traditional exponential function in the Verhulst model. Sigmoid formulations have been successfully demonstrated using numerous subcases of the Mittag-Leffler function. Additionally, researchers have successfully demonstrated the use of known memory kernels from the field of non-local (fractional) modeling in generating sigmoidal functions. Maple and Mathematica computing have enabled us to successfully visualize the results and identify emerging computational problems.

Special Sessions

Optimization and Control in Sustainable Computing Systems

Theme

This special session aims to bring together researchers and practitioners working at the intersection of optimization, control theory, and sustainable computing to address the growing energy and carbon footprint of modern computational systems. With the rapid expansion of cloud, edge, and AI-driven infrastructures, energy consumption and associated carbon emissions have become critical challenges. The session focuses on mathematically grounded optimization methods, advanced control strategies, and data-driven approaches that integrate carbon-awareness into computing systems. Emphasis will be given to practical and scalable solutions for energy-efficient and environmentally sustainable system design, operation, and management.

Topics

Carbon-conscious scheduling and resource allocation in cloud, edge, and distributed systems
Optimization models for minimizing carbon footprint and computational cost
Energy-aware and carbon-aware computing architectures
Advanced control strategies for dynamic power and carbon management
Mathematical modeling of carbon emissions in computing systems
Machine learning and data-driven methods for carbon prediction and optimization
Physics-informed and hybrid AI models for sustainable computing
Renewable energy integration in computing infrastructures
Digital twins for sustainable and carbon-aware system operation
Multi-objective optimization for energy–performance–carbon trade-offs
Real-time monitoring and control of energy and carbon metrics
Green data centers and sustainable enterprise computing
Carbon-efficient middleware, virtualization, and task allocation strategies
Adaptive and lightweight algorithms for energy-efficient computing
Algorithms for minimizing heat generation and cooling requirements
Sustainable software design and energy-aware code optimization
Edge intelligence and IoT systems for low-carbon computing
Benchmarking, metrics, and standards for carbon-aware computing systems

Physics-Informed Computational Intelligence for Energy-Efficient Systems

Prof. Dr. Ali Ahmadian, Decisions Lab, Mediterranea University of Reggio Calabria, Italy & Central University of Queensland, Australia
Prof. Dr. Soheil Salahshour, Faculty of Engineering and Natural Sciences, Istanbul Okan University, Istanbul, Turkiye

Theme

This special session brings together researchers at the convergence of physics-informed machine learning, computational intelligence, and energy systems engineering to address the pressing challenge of designing and operating energy-efficient computational and physical infrastructures. As modern systems from smart grids and edge-AI platforms to industrial IoT and data centres grow in complexity, purely data-driven or purely model-based approaches alone prove insufficient.

Physics-informed neural networks (PINNs) offer a principled bridge: embedding conservation laws, thermodynamic constraints, and system dynamics directly into learning architectures, yielding models that are accurate, interpretable, and physically consistent even under sparse measurement conditions. The session emphasises mathematically rigorous yet computationally tractable methods that couple PINNs, hybrid AI, and evolutionary optimisation with energy management, optimal control, and sustainable operation.
Contributions from both theoretical foundations and real-world deployments including renewable integration, thermal management, intelligent transportation, and green computing are warmly invited.

Topics
Physics-informed neural networks (PINNs) for energy system modelling and state estimation
PINNs and physics-informed operator learning (DeepONet, FNO) for PDEs in heat and fluid transport
Hybrid physics–data-driven models for real-time energy monitoring and anomaly detection
Computational intelligence methods (evolutionary algorithms, swarm intelligence, neuroevolution) for energy optimisation
Multi-objective optimisation for energy–performance–cost–carbon trade-offs in computing systems
Optimal control and model predictive control (MPC) with physics-informed surrogate models
Deep reinforcement learning for adaptive energy management in smart grids and microgrids
Energy-efficient edge AI and neuromorphic computing architectures
Physics-constrained neural networks for battery state-of-health and thermal degradation prediction
Digital twins for sustainable building, industrial, and data-centre energy management
Transfer learning and domain adaptation for energy systems with limited labelled data
Uncertainty quantification and robust optimisation in energy-aware intelligent systems
Thermodynamics-informed machine learning for HVAC, cooling, and industrial process optimisation
Physics-guided graph neural networks for power grid stability and fault diagnosis
Federated and distributed learning for privacy-preserving energy optimisation in IoT/edge networks
Benchmarks, datasets, and reproducibility standards for energy-efficient AI research
Applications: smart buildings, electric vehicles, renewable energy forecasting, green data centres, sustainable manufacturing

Mathematical Modeling, Fractional Calculus and Artificial Intelligence across Complex Systems of Systems: Theories, Computations and Applications

Prof. Dr. Yeliz Karaca, University of Massachusetts (UMass), Department of Mathematics and Department of Neurology, MA, USA
Prof. Dr. Dumitru Baleanu, Lebanese American University, Department of Computer Science and Mathematics, Beirut, Lebanon & Institute of Space Science, Magurele, Ilfov, Romania

Theme
Mathematical modeling accoutered toward establishing system-based modern models based on actual problems reflect different aspects of real-life challenges and complex systems along with their reciprocal dynamics and interactions through mathematics whilst addressing universal notions foregrounding their uniqueness, which enables the conceptualization, mechanization and automation of intellectual activity. This very essence sets out the solutions for problems in line with the results commensurately devised and calculated, which suggests that the core of a mathematical model lies in the factuality that it represents a dynamic simulation way of reasoning. Thus, mathematical modeling entails flexibility in employing the pertinent knowledge of mathematics, keen observation and analysis

of different phenomena in life so that the optimally applicable mathematical model(s) can be extracted [1].

Complexity, in this conjecture, reflects the disentangling of complex, dynamic, complicated, random, nonlinear, chaotic, adaptive, emergent systems, among many more, bringing about collective dynamics along with the interaction of components in multiple manners along with providing facilitation and acumen lenses in observing the problems through multiple perspectives. The representation of complex systems through models poses challenges owing to their inherent unpredictability and uncertainty as they are comprised of various interconnected entities that are in constant interaction with one another, which indicates the difficulties of modeling, entailing profound comprehension into the system's components and interactions thereof. Furthermore, the relationship between mathematical models, clinical applications and pattern formation is observed in such a way that mathematical models are employed for understanding complex systems and optimizing related processes. This mode aims to ensure the productive application of mathematical principles to problems in molecular and cell-related scopes of biology for the application of quantitative techniques of different sorts. In these regards, mathematical models are employed to advance the interpreting of complex processes, experimental notions and clinical realities [2].

Fractional calculus impacts the analysis of patterns in complex, dynamic, nonlinear, biological, ecological, medical to life systems, and advanced mathematical models decipher different processes of life along with novel approaches toward understanding various complex dynamic phenomena. Dynamic behaviors generated by modified networks are dependent on multiple parameter values based on fractional models particularly, which generates different patterns of periodic and excitable spiking, resting, chaos, bifurcation, parameter estimation and bursting behaviors with minimum computational errors [3]. Fractional dynamics, differentiation and systems in complex systems of systems as well as dynamical processes of fractional order with regard to natural and artificial phenomena are critical in terms of their modeling by ordinary or partial differential equations with integer order, ordinary and partial differential equations. Accordingly, fractional calculus and fractional-order calculus approach to provide novel mathematical models with fractional-order calculus employed in machine learning algorithms can ensure the obtaining of optimized solutions besides the justification of the requirement towards developing analytical and numerical methods. Within such systems, fractional calculus, fractals, wavelet, entropy to Artificial Intelligence (AI), machine learning, deep learning, and other models are employed or identifying complexities, self-similar patterns, symmetries, singularities and regularities stemming from otherwise irregular data [4].

Based on these integrative and multi-stage approaches across spatio-temporal scales with computer-assisted applications while building on our previous and ongoing special sessions, special issues and academic events, the current session aims to elucidate the ways that could serve for generating applicable solutions to pertinent problems encountered in different areas of mathematics, medicine, neuroscience, physics, genetics, biology, epidemiology, mathematical biology, computational biology, engineering, information science, computer science and data science, applied disciplines, among many others by extrapolating new mathematical theoretical directions in view of system-based modern models across different domains in real-world systems, natural systems, biological systems, life systems, nonlinear systems, complex systems and all other systems.

Topics

Fractional order differential/ integral equations and systems
Computational methods for fractional dynamics
Differential equations (i.e. Fractional, DEs, PDEs, ODEs) with uncertainty
Data-driven fractional biological/medical/epidemiological modeling
Data mining and voluminous data with mathematical modeling (ie. fractional calculus, stochastic (Itô) calculus, discrete/continuous models, stochastic models)
Fractional order observer design for nonlinear systems
Nonlinear modeling for biological/neurological/ epidemiological/medical diseases

Image/signal analyses based on soft computing
Wavelet analysis and applications
Entropy applications, processes and systems
Complex dynamics of network systems
Computational complexity
Dynamic systems on time scales
Symmetry, structure and synchronicity
Fractional-calculus-based control scheme for systems (i.e. complex, dynamic, chaotic)
Computational intelligence-based methodologies and techniques
Fractional- epidemiological neural networks (i.e. deep neural networks, machine learning) and mathematical modeling
Mathematical statistics and probabilistic scientific computing
Neurocomputation and neuronal circuits' dynamics
Bifurcation, chaos, complexity and applications to medicine, biology, engineering, technology and science
Mathematical modeling of virology, epidemiology, oncology, biology, and so forth
System- based mathematical analysis and modeling
Theories and/or applications of advanced AI (i.e. machine learning, deep learning, ensemble methods)
Quantum computation and optimization models of complex systems
Fractional mathematical modeling with computational complexity
Mathematical modeling and Artificial Intelligence (AI)

Modelling & Optimization in Engineering

Ramazan Yaman, Balikesir University, Turkey
Ahmet Sahiner, Suleyman Demirel University, Turkey
Fırat Evirgen, Balikesir University, Turkey

Theme

The goal of this session is to discuss recent developments in applications of optimization methods by bringing together researchers and practitioners working in the field of optimization theory, methods, software and related areas.

Topics

Mathematical programming
Global optimization
Nondifferential optimization
Continuous optimization
Combinatorial optimization
Multicriteria optimization
Equilibrium programming
Game theory
Data mining
Population based algorithms
Artificial intelligence technologies
Applications of optimization in natural sciences
Applications of optimization in engineering

Stochastic Modeling of Natural Phenomena

Assoc. Prof. Yassine Sabbar, Moulay Ismail University of Meknes, Boutalamine, Errachidia, Morocco
Prof. Waleed Adel, Nile University, Egypt
Assit. Prof. Abdulwasea Alkhazzan, Xi'an Fanyi University, Xi'an, China

Theme

This Special Issue will curate high-quality contributions presented at the conference and complementary submissions, highlighting rigorous analysis, modern numerical methods, and applications across the natural sciences.

Topics

Stochastic epidemic and eco-epidemiological models (SDEs, jump-diffusions, regime switching, PDMPs)
Lévy noise, rare events, heavy-tailed perturbations, and extreme-value-driven Dynamics
Stationary distributions, ergodicity, invariant measures, and long-time behavior
Extinction/persistence thresholds and noise-corrected reproduction metrics
Stochastic reaction–diffusion / SPDEs, random media, and spatially structured Dynamics
Fractional stochastic models and memory effects
Numerical schemes preserving positivity/stability (EM variants, tamed schemes, splitting, MLMC)
Data-driven identification (neural SDEs, operator learning, PINNs/PINOs for stochastic systems)
Uncertainty quantification, sensitivity analysis, and optimal control under uncertainty
Applications: climate variability, hydrology, population dynamics, geophysics, neuroscience, and biomedicine

Operational Research

Prof. Dr. Gerhard-Wilhelm Weber, Poznan University of Technology, Poland
Prof. Dr. Aslan Deniz Karaoglan, Balikesir University, Turkiye
Prof. Dr. Ibrahim Kucukkoc, Balikesir University, Turkiye
Assoc. Prof. Dr. Burcu Gurbuz, Johannes Gutenberg-University Mainz, Germany

Theme

This session aims to bring together researchers working on the topics related to operational research to discuss recent developments in the theory and application of operational research techniques.

Topics

Business analytics for manufacturing systems
Analytics, optimization and machine learning in manufacturing and supply chains
Intelligent manufacturing systems
Intelligent transpportation
Protfolio optimization
Network models
Inventory control, production planning and scheduling
Sustainable manufacturing
Robotics in manufacturing
Modeling, simulation, control and monitoring of manufacturing processes
Logistics, supply chains and networks
Facility planning and materials handling
Energy systems modelling
Design and reconfiguration of manufacturing systems

Fractional Calculus, Differential Equations and Artificial Intelligence in Complex Systems

Dumitru Baleanu, Lebanese American University, Lebanon
Yeliz Karaca, University of Massachusetts Chan Medical School (UMASS), Worcester, United States

Theme

Processes of fractional dynamics, differentiation and systems in complex systems as well as the dynamical processes and dynamical systems of fractional order with respect to natural and artificial phenomena are critical in terms of their modeling by ordinary or partial differential equations with integer order, ordinary and partial differential equations. Accordingly, fractional calculus and fractional-order calculus approach to provide novel mathematical models with fractional-order calculus employed in machine learning algorithms can ensure the obtaining of optimized solutions besides the justification of the requirement towards developing analytical and numerical methods. In that regards, complex systems and nonlinear dynamical systems are considered to be among the thriving models of natural phenomena, which are frequently characterized by unpredictable behavior whose analysis is challenging to be performed. The root of the problem lies in the understanding of which sort of information, especially concerned with their long-term evolution and memory properties, can be expected to be derived from those systems. Correspondingly, complexity, chaos, order and evolution all unravel the relationship between natural and social worlds, representing a modern process of thinking. Dynamical processes and dynamical systems of fractional order in relation to natural and artificial phenomena can be modeled by ordinary or partial differential equations with integer order, which can be described aptly by employing ordinary and partial differential equations. Thereafter, while the employment of artificial intelligence allows model accuracy maximization and functions' minimization like those of computational burden, novel mathematical-informed frameworks can enable a reliable and robust understanding of various complex processes that involve a variety of heterogeneous temporal and spatial scales. Such complexities necessitate a holistic understanding of different processes through integrative models with multi stages, being capable of capturing the significant attributes and peculiarities on the respective scales to expound complex systems whose behavior is confounding to predict and control with the ultimate goal of achieving a global understanding, while at the same time catching up with actuality along the evolutionary and historical path. Hence, the importance of generating applicable solutions to problems for various engineering areas, medicine, biology, mathematical science, applied disciplines and data science, among many others, requires predictability, interpretability and reliance on mathematical sciences, with Artificial Intelligence (AI) and machine learning being at the intersection with different fields marked by complex, chaotic, nonlinear, dynamic and transient components to validate the significance of the attained optimized approaches.

Based on this sophisticated integrative and multiscale approach with computer-assisted translations and applications, our special session aims at providing a bridge to merge an interdisciplinary perspective to open up new pathways and crossroads both in real systems and in other related realms.

Topics

Differentiability of solutions of differential equations with initial data
Advances of mathematical sciences, fractional calculus and differentiation
Fractional order differential, integral equations and systems
Computational methods of fractional order
Synchronization of dynamic systems on time scales
Data-driven fractional biological modeling
Data mining with fractional calculus methods
Fractional order observer design for nonlinear systems
Nonlinear modeling for epidemic/biological/neurological diseases

Fractional differential equations with uncertainty
Fractional dynamic processes in medicine
Image/signal analyses based on soft computing
Wavelet analysis and synthesis
Entropy of complex dynamics, processes and systems
Computational applied sciences
Control and dynamics of multi-agent network systems
Computational complexity
Nonlinear integral equations within fractional calculus in nonlinear science
Fractional dynamic processes in medicine
Fractional-calculus-based control scheme for uncertain dynamical systems
Computational intelligence-based methodologies and techniques
Bifurcation and chaos in complex systems
Mathematical analysis and modeling in complex systems
Quantum computation and optimization models of complex systems
Fractional mathematical modeling with computational complexity
Mathematical modeling and Artificial Intelligence in complex systems
Among many other related points with mathematical modeling

Control Theory & Applications

Metin Demirtas, Balıkesir University, Turkey
Amin Jajarmi, University of Bojnord, Iran

Theme

This session aims to discuss a broad range of topics including current trends of linear, nonlinear, discrete and fractional control systems as well as new developments in robotics and mechatronics, unmanned systems, energy systems with the goal of strengthening cooperation of control and automation scientists with industry.

Topics

Adaptive control
Linear and nonlinear control systems
Optimal control
Discrete time control systems
Robust control
Fractional order systems and control
Chaotic systems and control
Evolutionary and heuristic control
Robotic control
Energy management and control
Control of unmanned air and undersea vehicles

Fractional Calculus with Applications in Biology

Dumitru Baleanu, Lebanese American University, Lebanon
Necati Ozdemir, Balikesir University, Turkey

Theme

The goal of this session is to bring together creative and active researchers, in theoretical analysis and numerical tools, to discuss recent developments in applications of fractional order models of biological models. Fractional order models have become ubiquitous research topics in the last few decades. Their memory property contributes to a better and profound understanding of the dynamics of real world models, namely of biological population problems. Stochastic and deterministic models and coinfection models, as well as computational models, are welcome for HIV, HCV, Ebola, Zika, etc, in this session.

Topics

New numerical methods to solve fractional differential equations
Deterministic and stochastic fractional differential equations
Computational methods for fractional differential equations
Bifurcation theory
Stability theory
Cancer development models: chaos, synchronization
Applications in bioengineering, medicine, ecology, biology, epidemiology

Nonlinear Dynamical Systems and Chaos

Huseyin Merdan, TOBB ETU, Turkey
Songul Kaya Merdan, METU, Turkey

Theme

This special session focuses on the dynamics of complex systems, which are one of the most attractive subjects of the modern sciences. The attractiveness of this particular area arises from two different aspects: The first one is that it provides challenges, which are connected with many uncertainties in description of irregular motions. The second one is methods of investigation, which are not yet well developed and established. Applications of complex dynamics investigations are very important and deal with a wide range of problems. They begin with mechanical problems and extend to earthquake prediction and social sciences problems. We are interested in those investigations in electrical and mechanical engineering, physics, biology, economics, finance, neuroscience, computer sciences, fluid dynamics and earthquake monitoring, which urgently need mathematical modeling of their problems and analysis through nonlinear dynamical systems approach.

Topics

ODE, DDE and PDE based modelling for complex systems
Dynamical systems and chaos
Bifurcation theory
Synchronization
Control theory
Fluid Dynamics
Stochastic complex dynamical systems and randomness
Hybrid systems
Complex networks based-models
Neural Networks
Bio-engineering, bio-imaging and bio-fluids
Population dynamics and conservation biology

Ecosystems
Evolution and ecology
Epidemiology and disease modeling
Neuroscience
Regulatory networks
Cell and Tissue biophysics
Evolution and populations genetics
Cell and developmental biology
Cancer and immunology
Environmental sciences
Social economy systems
Climate change
Financial engineering
Mathematical finance

Nonlinear Transport Phenomena and Models

Jordan Hristov, Univ. of Chemical Tech. and Metallurgy, Bulgaria

Theme

The special session focuses on modelling of nonlinear transport phenomena (heat, mass and momentum) as well as models related to real world application. Models with both local and fractional differential operators involved in modelling in such models are welcome. The topics drawn below are the main directions but no restrictive and any new problems outside them are welcome.

Topics

Nonlinear diffusion and heat transfer (conduction)
Nonlinear viscoelasticity and plasticity
Modelling rheology of complex fluids, solids and granular systems (hydrodynamics, large strain deformations and mixing)
Nonlinear kinetic and rate equations and irreversible thermodynamics
Models of nonlinear biological and medical problems for real-world applications
Models for treatment of nonlinear signal processing and control
Nonlinear electrical and magnetic phenomena and nonlinear applied models in electrotechnics (nonlinear magnetic circuits, high frequency skin effects, supercapacitors, etc.)
Inverse problems in nonlinear models of transport phenomena
New nonlinear models (broad aspect)
Analytical and numerical methods for solution of nonlinear models
Scaling and dimensional analysis

Energy Management and Optimization

Ramazan Yaman, Balikesir University, Türkiye
Hakan Akca, Ege University, Türkiye

Theme

This session aims to gather researchers in the field of power and energy systems to delve into recent developments in both the theoretical aspects and practical applications of electricity markets, including power system applications.

Topics

Optimization in Power Delivery and Generation
Demand Response and Participation in Electric and Energy Systems
Hybrid Electricity Markets and Their Integration into Existing Market Structures

Energy Storage Technologies and Solutions in Electric Industry
Energy Use in Residential Areas
Energy Usage in the Transport Sector and Electric Vehicles
Robust/Stochastic/Heuristic Control and Optimization Methods for Energy Systems
Decision Support Systems for Energy Systems
AI/ML-Based Energy Optimization Techniques
The Optimization of Distributed Renewable Energy Resources and the Electricity Market Control
Transmission Markets, Congestion Management, and Grid Reliability
Consolidation of Smart and/or Micro Grids and Distribution Networks, and Integrating in Electricity Markets
Geothermal Energy Systems
Energy Efficiency and Conservation

Theories and Applications of Discrete Fractional Operators

Thabet Abdeljawad, Department of Mathematics and Sciences, Prince Sultan University, Saudi Arabia
Sumati Kumari Panda, Department of Mathematics, GMR Institute of Technology, India

Theme

Fractional calculus was first proposed in the year 1695. Many well-known mathematicians, including Leibniz, L' Hospital, Riemann, and others, contributed to this study. The fractional calculus has been widely employed in a variety of fields due to its interesting memory effects and non-locality. In the last decade, it has become one of the most popular fields of applied mathematics.
Discrete fractional calculus was proposed very recently. Although discrete and fractional mathematics have always played an important role in mathematics, their importance has recently grown in several branches, including but not limited to topological indices, polynomials in graphs, molecular descriptors, differential of graphs, alliances in graphs, domination theory, complex systems, discrete fractional delta operator, discrete fractional nebla operators, discrete geometry, fractional differential equations, discrete fractional integral inequalities, discrete fractional differences, discrete fractional sums and more.
The collection will bring together primary research studies that explore the applications of discrete fractional with applications in engineering and the natural sciences.

Topics

Existence theory of discrete fractional order systems
New numerical methods for the solution of fractional difference equations
Dynamics of discrete fractional-order systems in engineering and natural sciences
Theory and application of q-fractional operators
Stability analysis of discrete fractional-order neural networks systems
Discrete fractional inequalities and iterative methods
Existence and uniqueness of solutions for discrete fractional equations
Monotonicity and convexity of fractional difference operators

Contents

Preface 3
Conference Committee 4
Conference Program 6
Zoom Connection Links 9
About Cunda 10
Plenary Speakers 11
Special Sessions 15
Contents 25
Abstracts 30
A Mathematical Modeling Approach for the Dynamic Analysis of Metabolic Disease Progression 31
PINNs Meet Stabilized Finite Element Methods for Time-Dependent Convection-Dominated PDEs 32
Metaheuristic Guided Neural Architecture Search for Efficient Engineering AI Systems 33
Tomato Fruit Ripeness Classification and Counting with YOLO models 34
A Low-Complexity Mathematical Framework for HQAM Decoding 35
Stochastic and exact solutions of a Stochastic Korteweg de Vries equation with Gaussian white noise 36
AI-Enabled Beamforming and Dynamic Spectrum Allocation for Reliable Long-Range IoT over 6G 37
Fourier Analysis of the Tsunami Doublet of the 6 February 2023 Kahramanmaraş (Türkiye) Earthquake Using Arsuz Tide-Gage Records 38
Mass Optimization of a Composite Cylindrical Skirt Structure Using Genetic Algorithm and Particle Swarm Optimization 39
Real-Time Optimal Control of Quadrotor Dynamics via Physics-Informed Recursive Least Squares 40
Solving the 3D Bin Packing Problem for Heterogeneous Vehicles Using an Empty Maximal-Spaces Based Genetic Algorithm 41
Order Picking Route Optimization in Warehouses Using Virtual Node Aggregation 42
Time-Periodic Solutions for Coating Flow on A Rotating Elliptic Cylinder 43
Cardinality Constrained Risk Parity on a Sharpe Filtered Subset of the BIST 100 Index 44
Lexicographic approach for multi-objective humanitarian allocation problem 45
On Oresme Sequence Spaces 46
Physics-Informed Neural Networks for Periodic Sturm-Liouville Eigenvalue Problems 47
Reconstruction of Hydraulic Transients in Surge Tanks and Pipelines via Compressive Sensing and Discrete Cosine Transform 48
Neural Network-Based Computational Solutions of the Kairat-II-X Equation 49
Parameter Sensitivity Analysis of an Online Gaming Addiction Model 50
A Multilevel ID-Tucker-FFT Acceleration Scheme for Volume Integral Equation Solvers in 2D Scattering Problems 51
Dual Reciprocity BEM Solutions of Nonlinear Wave Equations in Cracked Regions 52
Numerical Solutions of 3D MHD Equations using Differential Quadrature Method 53
Strong Convergence of a Regularized Inertial Projection Method for Variational Inequality Problems 54

Coupled Fundamental Solution of 3D MHD Equations and the Method of Meshless Fundamental Solution Application 55

Physics-Informed Neural Network Surrogate Modelling for Real-Time Prediction of Rain-Induced Leading-Edge Erosion in Offshore Wind Turbine Blades 56

Optimizer Plugger and NoiseLayer: Elegant way of Deep Learning 57

Physics-Informed Feature Engineering for Photovoltaic Power Forecasting Using Inverter Telemetry 58

Forecast Horizon Matters: Explicit Temporal Memory Design for Multi-Horizon HVAC Load Forecasting 59

Effect of Viscous Dissipation on Pulsating Flow and Heat Transfer for Non-Newtonian Fluid in a Pipe 60

A Neural-Network-Based Framework for Cryptographic Systems under Hawkes-Driven Attacks 61

Diffusion bridge with random terminal time arising in fish population dynamics 62

A Physics-Informed Neural Network Framework for the Brusselator Reaction–Diffusion System with Cross-Diffusion 63

Attention U-Net for SAR Backscatter Prediction from Sentinel-2 Imagery in the Aralkum Desert: An Optical-to-SAR Translation Framework 64

Numerical computation of Fisher-Rao gradient flow to understand the biological structure of radiolarians 65

On the BEM and the MFS solutions of diffusion equations in coupled domains 66

Hyper-Heuristic Solution Approaches for the Dual Resource Constrained Flexible Job Shop Scheduling Problem with Heterogenous Worker Flexibility 67

A Fuzzy Logic-Based Musical Cryptography Model for Text-to-Note Transformation 68

Prony series representability of some fractional viscoelastic materials 69

A Mathematical Model of Glymphatic Dysfunction and Neuroinflammation in Multiple Sclerosis 70

Operational Research Applications in Agriculture: Trends, Methods, and AI Integration 71

Explainable Climate Intelligence Through Temporal Feature Engineering 72

When Should We Translate? A Translation-Aware Probabilistic Routing Framework for Cost-Efficient Multilingual Text Classification 73

Localized Magnetic Control of MHD Mixed Convection of Casson Fluid in a Lid-Driven Cavity: A DRBEM Approach 74

A Customer Behavior-Informed Framework for Demand Forecasting and Inventory Optimization Using Machine Learning and Mixed-Integer Programming 75

A Preliminary Machine Learning Framework for Network Lifetime Estimation in Grid-Free Wireless Sensor Networks 76

Deep Learning Analysis of the Higgs Boson in de Sitter Space-Time Using PINN 77

A Novel Entropy-SWARA Weighted Intuitionistic Fuzzy Hierarchical Clustering Framework for Sustainable Smart City Investment Prioritization 78

A Spatiotemporal Framework for Classifying Boarding Demand Among Passengers with Disabilities 79

A Genetic Algorithm for Resource Allocation and Scheduling in Agile Project Management: A Case Study 80

Robust and Sustainable Commercial Waste Collection with Inventory and Carbon Emission Constraints 81

A Computational Study of Parameter-Dependent Magnetohydrodynamic Flows 82

A Simulation–Optimization Framework for Multi-Elevator Systems Using Polling Models and Hyperparameter Tuning 83

Energy and Carbon Intensity Performance of BIST Sustainability Firms: A Multi-Period MCDM Approach 84

Double Local Fractional Natural Transform Approach for Fractional Partial Differential Equations 85

Common Due Date Assignment and Scheduling for Unrelated Parallel Machines 86

A Deep Learning Synchronizer for Fractional-Order Chaotic Secure Communication: Application to Renewable-Energy-Based Electric Vehicle Charging Stations 87

Fuzzy-Enhanced Synergy-Driven R&D Project Portfolio Selection under Uncertainty: A Distributionally Robust and Cooperative Game-Theoretic Framework 88

Dirac magnetic monopole: The MICZ–Kepler problem as a subset of the Bağcı–Hoggan differential equation 89

A Multi-Commodity Flow Optimisation Model for Sustainable Port–Hinterland Freight Transport Planning 90

A Structural Aspect of Module Classes 91

Ranking Syrian Governorates Based on Humanitarian Sectoral Needs Using an Entropy-Based MOORA Approach 92

A Nonlinear Median Filter Regularization Operator for Geophysical Inversion 93

Life Cycle Cost and Emission-Based Multi-Objective Optimization of Net-Zero Renewable Energy Microgrids 94

Blockchain-Integrated Life Cycle Carbon Footprint Management and Decision Support Model for Solar Power Plants 95

Local Stability and Hopf Bifurcation in a Three-Dimensional Photocatalytic Microplastic Reactor Model with Adaptive Gain 96

Optimal transport for Empirical Bayes estimation for Wavelet analysis with spatial single cell data 97

Bifurcation, Chaos, and Control in a Discretized Fractional-Order Ecological Model 98

Optimal transport trajectories for deep cardiovascular spatial single cell data 99

A Statistical and Mathematical Approach for Estimating Time-Varying Parameters in a SIRD Model of COVID-19 Outbreak 100

A Diagonal-scaled Conjugate Gradient Algorithm for Large-Scale Unconstrained Optimization with Application to Regularization-Free Image Denoising 101

A Fuzzy-Evolutionary Game Theory Framework for Patent Portfolio Management in Technology Transfer Offices 102

A Theoretically Grounded Attention-DenseNet with Dual Stochastic Activations for Mammographic Cancer Classification on INbreast and MIAS 103

Structural Analysis of a Dynamically Constrained Mobile Facility Location Problem on Tree Networks 104

A Multi-Objective Decision Support Model for Electric Bus Configuration Selection: A Pareto-Optimality Approach 105

Convergence Theorems for the McShane Integral in Locally Convex Riesz Spaces 106

Dynamic Programming using Average-Value-at-Risk Criteria 107

Integrating exclusion constraints into the Traveling Salesman Problem: An Application to Formula 1 Calendar Design 108

Physics-Informed Neural Network Approximation of Nonlocal Transport Models for Engineering Density-Flow Simulation 109

Qualitative Analysis and Numerical Simulation of a Caputo Fractional-Order Lyme Disease Model with Wildlife-Maintained Tick Infection Pressure 110

Explainable Fractional-Order Intelligent Predictive Control Framework for Nonlinear Cyber-Physical Systems under Uncertainty 111

Optimization in Machine Learning: Training Models Through Loss Function Minimization 112

Comparative Evaluation of Clustering Algorithms for Customer Complaint-Based Failure Analysis in the HVAC Industry 113

An integrated AHP-based MCDM module for vendor quotation ranking in SAP ABAP 114

Homoclinical Structure of Impulsive SICNNs 115

A Stochastic Hybrid Energy System Model Consisting of Natural Gas, Hydroelectric and Wind Power: Stability Analysis and Carbon Emission Dynamics 116

A Carbon-Aware Algorithm Selection Framework for Wind Turbine Power Prediction Using SCADA Data 117

Heating Energy Demand Forecasting Using Different Regression Techniques Based on the Building Wall Envelope Heat Transfer Coefficient 118

Cooperative Value Analysis of Repowering Strategies in Heterogeneous Wind Farms under Wake Interactions 119

Impact of Core Materials on Performance of Wound Rotor Synchronous Generators 120

Design of an Intelligent Student Tracking System Based on Educational Data Mining 121

Forecasting Türkiye's Hourly Net Load via LSTM Models with Different Input Configurations 122

Data-Driven Soiling Loss Estimation and Cleaning Schedule Optimization for a Rooftop Photovoltaic System 123

Residual co-implication based fuzzy partial metric spaces: An application to image denoising 124

Evaluating Machine Learning Classifiers for Market Prediction in the Traveling Purchaser Problem 125

Carbon-Conscious Energy Efficiency Assessment Using Explainable Artificial Intelligence and Multi-Criteria Optimization: Evidence from Borsa Istanbul Firms 126

A Truck–Drone Routing Problem for Post-Earthquake Damage Assessment 127

FEA-Based Design and Analysis of a Brushless Excitation Machine for a Medium-Voltage Synchronous Generator 128

A Scenario-Based Optimization Framework for End-of-Life Electric Vehicle Battery Recycling Network Design in Türkiye 129

A Review of Parallel Radial Basis Function and Bayesian Methods for High-Dimensional Expensive Black-Box Optimization 130

Optimal Placement of Photovoltaic, Electric Vehicle Charging Stations, and Battery Energy Storage Systems in Distribution Networks Using a Hybrid CHAO 131

Hosoya Matrix Method for Linear Pantograph Differential Equations 132

High-Dimensional Expensive Black-Box Constraint Satisfaction and Optimization Using Surrogate-Assisted Evolutionary Algorithms 133

Approximate Controllability of Ψ-Hilfer Fractional Stochastic Differential Systems of Order $1 < \mu < 2$ 134

Multi-Layered Artificial Intelligence and Robotic Process Automation in Supply Chain Management 135

Experimental Analysis of the Thermal Performance Effects of Enclosure Roof Geometry in Dry-Type Transformers 136

Assessment of Spatial Accessibility and Wayfinding Performance in University Campuses: A Case Study of Atlas University Vadi Campus 137

Energy Optimization in Paper Manufacturing 138

Asymptotically Unpredictable Solutions of Quasilinear Systems with Delay 139

A New Kind of Motion in Semiflows: Asymptotically Unpredictable 140

Modelling of Geothermal Gradient Distribution in the Balıkesir Region via Physics-Informed Neural Networks (PINNs) 141

Priority-Driven Portfolio Optimization of Interacting Energy Efficiency Measures: A Multi-Mode MILP Framework with Exact Interaction Modelling 142

Bridging Classical Solvers and Learned Operators: A JAX Framework for Hybrid Forward and Inverse Problems 143

Mathematical Modelling of the Photoluminescence Behavior of a Carbazole-Based Schiff Base Compound and Examination from the Perspective of DFT Analysis and Sustainable Material Design 144

MobileViTv2 Model Based- Fractional Gastrointestinal Endoscopy Images of Computer Vision Systems per Chaotic Learning Rate Scheduling 145

Integrated Optimization of Distributed Human–Robot Collaborative Disassembly Line Balancing, End-of-Life Product Transportation, and Outbound Distribution Routing 146

Discrete-time prey-predator interaction with moonlight-driven predation and water-dependent growth 147

An Adaptive PINN Approach for the Simulation of Magnetofluid Electroosmotic Flow of Micropolar Fluids through a Rotating Circular Microchannel in the Presence of AC Current and High Zeta Potential 148

Comparative Evaluation of Deep Learning Architectures for State-of-Charge Estimation of Lithium-Ion Batteries 149

Spatial Heterogeneity in Provincial Housing Sales in Turkey: A Comparative Analysis of OLS, SAR, SEM, and GWR Models 150

E-Bayes Estimation of the Rayleigh Distribution for Wind Energy 151

On the fractional-order differential models for AI-Based optimization in sustainable computing systems under complex constraints 152

Rich, Green and Safety Focused Route Optimization 153

Mathematical Analysis of a Cholera Model with Environmental Reservoir and Behavioral Awareness 154

The Effect of the Splitting Protocol on Performance in Dermatoscopic Skin Lesion Classification: A Controlled Measurement of Data Leakage 155

A QoS-Integration-Centric Taxonomy and Mathematical Modeling Perspective of Opportunistic Routing in Wireless Mesh Networks 156

Subdivisions of Sierpinski Triangle Graphs and Their Topological Graph Indices 157

Advanced qualitative and sensitivity analysis of deterministic Lanchester-type area-fire warfare models 158

A Computationally Stable Memory-Aware Physics-Informed Neural Network Framework with Caputo Fractional Operators: Convergence Theory and Applications to Long-Memory Data 159

Physics-Informed Neural Network-Based Modeling of Cancer Dynamics under Combined Impact of Chemotherapy and Immunotherapy 160

Initial-Value Admissibility and Left-Half-Plane Stability of Power-Law Fractal-Fractional Systems 161

Mixed Sumudu–Adomian Method for Two-Dimensional Nonlinear Fuzzy Integral Equations 162

Cryptocurrency Price Prediction Using an Automatic Programming Method 163

Author Index 164

Subject Index 167

Abstracts

A Mathematical Modeling Approach for the Dynamic Analysis of Metabolic Disease Progression

Taha Yılmaz✉, Fırat Evirgen

Balıkesir University, Mathematics Department, Balıkesir, Türkiye

Abstract

In this study, a new compartmental mathematical model is proposed to investigate the dynamic progression of metabolic disorders associated with hypothyroidism, obesity, and diabetes. The proposed model consists of five compartments representing different health states within the population. The well-posedness of the model is established by proving the existence and uniqueness of solutions. In addition, the positivity and boundedness of the solution space are demonstrated, ensuring that the model is biologically meaningful.

Equilibrium points of the model are obtained, and their stability properties are analyzed in order to understand the long-term behavior of the system. Furthermore, numerical simulations are performed using the fourth-order Runge–Kutta method. Through these simulations, the effects of model compartments and key parameters on the overall system dynamics are investigated. The results provide a mathematical framework for understanding the interaction between hypothyroidism-related obesity and diabetes progression and may offer useful insights for future theoretical and applied studies on metabolic disease dynamics.

Keywords: Metabolic disease Dynamics, Obesity–diabetes progression, Hypothyroidism, Mathematical model, Equilibrium analysis, Runge–Kutta method

Acknowledgements

This study was supported by the TÜBİTAK 2209-A University Students Research Projects Support Program.

References

[1] Gupta, S., & Kumar, D. (2019). A mathematical model to study the effects of genetic and environmental factors on obesity and type 2 diabetes. Applied Mathematics and Computation, 347, 530–544.

[2] Du, J., Li, X., & Chen, G. (2018). A mathematical model of obesity and diabetes with delay. Applied Mathematics and Computation, 332, 253–266.

[3] Song, B., Zhang, Z., & He, D. (2019). A mathematical model of obesity and diabetes with optimal control. Advances in Difference Equations, 2019(1), 1–16.

[4] Evirgen, F., Uçar, S., & Özdemir, N. (2026). Mathematical analysis and optimal control of a Caputo fractional diabetes system with parameter identification. Journal of Computational and Applied Mathematics, 477, 117151.

✉ Corresponding Author Email: *tahay1069@gmail.com*

PINNs Meet Stabilized Finite Element Methods for Time-Dependent Convection-Dominated PDEs

Süleyman Cengizci[1]✉, Ömür Uğur[2], Srinivasan Natesan[3]

[1] *Department of Computer Technologies, Antalya Bilim University, Antalya, Türkiye*
[2] *Institute of Applied Mathematics, Middle East Technical University, Ankara, Türkiye*
[3] *Department of Mathematics, Indian Institute of Technology Guwahati, Guwahati, India*

Abstract

Convection-dominated time-dependent partial differential equations arise in numerous scientific and engineering applications, yet their accurate numerical treatment remains a persistent challenge. When convection dominates diffusion, standard finite element discretizations tend to exhibit spurious oscillatory behavior. Stabilized formulations, particularly the streamline-upwind/Petrov–Galerkin (SUPG) approach combined with YZβ discontinuity-capturing operators [2], can effectively mitigate such artifacts; however, residual smearing of sharp fronts and localized overshoots may still occur. On the other hand, physics-informed neural networks (PINNs) [3], despite their flexibility, face well-known difficulties in capturing thin layers characteristic of singularly perturbed problems and often demand extensive training. In this study, we propose a coupled computational strategy that leverages the strengths of both paradigms [1]. The stabilized finite element solver provides a robust initial approximation over the full time history, while a neural network corrector—trained on a narrow temporal window near the final time—refines the solution by simultaneously fitting the finite element data and minimizing the strong-form PDE residual through automatic differentiation. A selective enforcement mechanism excludes boundary-adjacent collocation points from the residual loss, preserving layer integrity. The network employs random Fourier feature mappings and residual block connections to represent multiscale solution features, and a multi-phase adaptive weighting schedule transitions the optimization from data-driven to physics-driven learning. The methodology is validated on a suite of one- and two-dimensional benchmark problems involving boundary layers, interior layers, propagating fronts, and nonlinear self-steepening dynamics, consistently yielding improved terminal-time accuracy over the standalone stabilized finite element approximations [4].

Keywords: physics-informed neural networks, stabilized finite elements, convection-dominated flows, SUPG, shock-capturing, hybrid methods

Acknowledgements

The first author was supported by TUBITAK under Grant Number 225M468.

References

[1] Cengizci, S., Uğur, Ö., & Natesan, S. (2026). A PINN-enhanced SUPG-stabilized hybrid finite element framework with shock-capturing for computing steady convection-dominated flows. Adv. Eng. Softw., 216, 104135.
[2] Tezduyar, T.E., & Senga, M. (2006). Stabilization and shock-capturing parameters in SUPG formulation of compressible flows. Comput. Methods Appl. Mech. Eng., 195, 1621–1632.
[3] Raissi, M., Perdikaris, P., & Karniadakis, G.E. (2019). Physics-informed neural networks: A deep learning framework for solving forward and inverse problems involving nonlinear PDEs. J. Comput. Phys., 378, 686–707.
[4] Cengizci, S., Uğur, Ö., & Natesan, S. (2022). SUPG-YZβ computation of chemically reactive convection-dominated nonlinear models. Int. J. Comput. Math., 100, 283–303.

✉ Corresponding Author Email: *suleyman.cengizci@antalya.edu.tr*

Metaheuristic Guided Neural Architecture Search for Efficient Engineering AI Systems

Ali Berkol✉, İdil Gökçe Demirtaş

ASELSAN-Ulak, Projects and Business Development, Ankara, Turkey

Abstract

Recent advances in artificial intelligence have significantly increased the demand for efficient deep learning models in engineering applications. However, designing optimal neural network architectures remains a challenging task, as the search space of possible architectures grows exponentially with the number of layers, connections, and hyperparameters. Neural Architecture Search (NAS) has emerged as a promising approach to automate this design process, yet many existing NAS techniques rely on reinforcement learning or gradient-based optimization methods that often require substantial computational resources. This study proposes a metaheuristic-guided Neural Architecture Search framework designed specifically for engineering-oriented artificial intelligence systems. The proposed approach formulates the architecture search problem as a combinatorial optimization task and utilizes population-based metaheuristic algorithms to efficiently explore the architecture space. Candidate neural architectures are encoded as structured representations, allowing evolutionary operators such as mutation and recombination to generate diverse model configurations. The search process is guided by a multi-objective fitness function that considers model accuracy, computational complexity, and architectural efficiency. The proposed framework enables a more flexible and computationally efficient exploration of neural network architectures compared to conventional NAS approaches. By leveraging the global search capabilities of metaheuristic optimization, the method aims to reduce the risk of premature convergence and improve the diversity of candidate solutions. The effectiveness of the approach is demonstrated through experiments on representative engineering datasets, highlighting its potential to produce high-performance neural architectures while maintaining manageable computational costs. The results indicate that metaheuristic-guided architecture search provides a promising alternative for automated deep learning model design in complex engineering systems. The proposed framework contributes to the growing intersection of applied mathematics, optimization, and artificial intelligence by introducing a flexible methodology for discovering efficient neural architectures in engineering applications

Keywords: Neural Architecture Search, Metaheuristic Optimization, Evolutionary Algorithms, Engineering Artificial Intelligence, Combinatorial Optimization

References

[1] B. Zoph and Q. V. Le, "Neural Architecture Search with Reinforcement Learning," *Proceedings of the International Conference on Learning Representations (ICLR)*, 2017.

[2] T. Elsken, J. H. Metzen, and F. Hutter, "Neural Architecture Search: A Survey," *Journal of Machine Learning Research*, vol. 20, no. 55, pp. 1–21, 2019.

[3] T. White, S. Neiswanger, and Y. Savani, "BANANAS: Bayesian Optimization with Neural Architectures for Neural Architecture Search," *Proceedings of the AAAI Conference on Artificial Intelligence*, vol. 35, no. 12, pp. 10293–10301, 2021.

✉ Corresponding Author Email: ali.berkol@yahoo.com

Tomato Fruit Ripeness Classification and Counting with YOLO models

Tugba Aydemir ✉

Yalova University, International Trade and Finance Department, Yalova, TURKEY

Abstract

Determining the ripeness of tomatoes and counting the fruits is traditionally done by hand, which is a time-consuming and laborious task. Using technology to accomplish these tasks will not only ensure that work is completed on time when human resources are insufficient, but will also provide convenience. Therefore, there is a need to develop algorithms that will enable robots, especially those to be used in agriculture, to perform fruit picking and counting operations.

Deep learning algorithms have been increasingly applied and tested in agriculture in recent years for fruit and vegetable ripeness detection, particularly tomato fruit ripeness detection. Because it is difficult to distinguish the color of green tomatoes against the background, the subject of green tomato identification is rarely studied. In this study, different versions of the YOLO (You Only Look Once) algorithm will be used to determine the maturity levels and number of tomato fruits from images of tomatoes grown in a greenhouse environment. The images used in this study were taken from the Laboro Tomato dataset, a tomato dataset collected at various stages of ripening available on Kaggle repository. The dataset consists of 805 images collected under various environmental conditions such as illumination, shading, overlap, and occlusion. Then, the collected tomato images from different sources are used to test the models.

The experimental results show in the training stage that mean average precision (mAP) of YOLOv8, YOLOv9, YOLOv10, YOLOv11, YOLOv12, and YOLOv26 are 81.6%, 86.1%, 84.4%, 87.4%, 86.4%, and 88.3%, respectively. Furthermore, the YOLO family performs exceptionally well not only in distinguishing green tomatoes from the background but also in identifying tomatoes in general based on their ripeness level.

Keywords: YOLO, Convolutional neural networks, tomato fruit ripeness classification, tomatoes counting.

References

[1] "Laboro Tomato" Kaggle.com [online]. Available from: https://www.kaggle.com/datasets/gunavenkatdoddi/eye-diseases-classification, [Accessed: 20 March 2026].
[2] Zeng, Q., Miao, Y., Liu, C., & Wang, S. (2009). Algorithm based on marker-controlled watershed transform for overlapping plant fruit segmentation. Optical Engineering, 48(2), 027201-027201.
[3] Appe, S. N., Arulselvi, G., & Balaji, G. N. (2023). CAM-YOLO: tomato detection and classification based on improved YOLOv5 using combining attention mechanism. PeerJ Computer Science, 9, e1463.
[4] Yang, D., & Ju, C. (2024). Performance comparison of cherry tomato ripeness detection using multiple YOLO models. AgriEngineering, 7(1), 8.
[5] Wang, S., Xiang, J., Chen, D., & Zhang, C. (2024). A method for detecting tomato maturity based on deep learning. Applied Sciences, 14(23), 11111.
[6] Huang, W., Liao, Y., Wang, P., Chen, Z., Yang, Z., Xu, L., & Mu, J. (2025). AITP-YOLO: improved tomato ripeness detection model based on multiple strategies. Frontiers in Plant Science, 16, 1596739.

✉ Corresponding Author Email: *tgb.aydemir@yalova.edu.tr*

A Low-Complexity Mathematical Framework for HQAM Decoding

Neriman Şolt✉, Murat Güzeltepe

Sakarya University, Department of Mathematics, Sakarya, Türkiye

Abstract

By offering superior lattice packing density, hexagonal quadrature amplitude modulation (HQAM) is a promising scheme for maximizing spectral efficiency in next-generation communications. Nevertheless, the prohibitive computational overhead associated with optimal maximum likelihood (ML) decoding hinders its real-world applicability. Addressing this challenge, this study formulates a low-complexity mathematical framework based on a dynamically optimized hybrid algorithm to ensure computationally sustainable detection. At the core of this hybrid mathematical framework is the algebraic construction of error-correcting codes over the ring of Eisenstein integers, which inherently aligns with the hexagonal lattice structure of HQAM. By formally defining correctable error sets derived from these codes, the proposed architecture intelligently partitions the search space. Upon receiving a distorted signal, the algorithm evaluates these predefined mathematical sets to identify and extract only the lattice points geometrically closest to the received vector. These isolated points formulate a highly restricted, high-probability candidate pool. Consequently, the ML decoding process is executed exclusively within this localized subspace rather than across the exhaustive global constellation. By systematically eliminating highly improbable lattice points, this targeted search strategy mathematically guarantees the exact symbol error rate (SER) performance of a conventional exhaustive ML detector over both additive white Gaussian noise (AWGN) and fading channels, while significantly reducing the computational overhead.

Keywords: Hexagonal QAM, low-complexity decoding, search space optimization, Rayleigh fading channel.

Acknowledgements

This work was supported by The Scientific and Technological Research Council of Türkiye (TÜBİTAK) with Project Number 125E211.

The first author acknowledges the support of TÜBİTAK through the Directorate of Science Fellowships and Grant Program (BİDEB) under the 2211-A National PhD Fellowship Program.

References

[1] Conway, J.H., & Sloane, N.J.A. (1999). Sphere packings, lattices and groups. New York, NY, USA: Springer.
[2] Leung, E., Dong, Z., & Zhang, J-K. (2016). Uniquely factorable hexagonal constellation designs for noncoherent SIMO systems. In IEEE Transactions on Vehicular Technology, vol. 66, no. 4, 5495-5501.
[3] Damen, M.O., Gamal, H. El., Caire, & G. (2003). On maximum-likelihood detection and the search for the closest lattice point. In IEEE Transactions on Information Theory, vol. 49, no. 10, 2389–2402.
[4] Proakis, J. G., & Salehi, M. (2001). Digital communications. New York, NY, USA: MC Graw-Hill, vol. 4, 593-620.

✉ Corresponding Author Email: *neriman.solt2@ogr.sakarya.edu.tr*

Stochastic and exact solutions of a Stochastic Korteweg de Vries equation with Gaussian white noise

Esma Ulutaş✉

Karadeniz Technical University, Department of Electronics and Communication Engineering, Trabzon, Turkey

Abstract

Nonlinear partial differential equations (NPDEs) are widely recognized as fundamental tools for understanding a broad spectrum of physical phenomena across various scientific disciplines. It is also well established that Stochastic (NPDEs) are generally more difficult to analyze than deterministic equations because of the inclusion of additional random terms [1-4]. In this study, we investigate a stochastic Wick-type nonlinear partial differential equation with conformable derivatives. We consider stochastic Korteweg de Vries equation with Gaussian white noise. Exact and stochastic solutions are obtained through the extended G′/G method, white noise theory, and Hermite transforms. Moreover, a specific example is provided to demonstrate how these solutions may be represented as Brownian motion functional solutions.

Keywords: White noise theory, Stochastic NPDEs, extended G′/G method.

References

[1] Holden H., Øksendal B., Ubøe J. and Zhang T., Stochastic partial differential equations: A Modeling, White Noise Functional Approach. Birkhäuser, Basel, 1996.
[2] Li, Y., et al., Stochastic Exact Solutions of the Wick-Type Stochastic NLS Equation, Appl. Math. Comput., 249 (2014), pp. 209-221.
[3] Liang S., Wu K.N., Djehiche B., Hu X., Asymptotic stabilization for stochastic generalized Burgers–KdV equations with Lévy noise, Chaos, Solitons & Fractals, 204 (2026), 117780.
[4] Alnafisah Y., Ahmed H. M., Rabie W. B., Modulation instability, stochastic soliton dynamics, and analytical solutions in the Fokas-Lenells equation with quadratic-cubic nonlinearity, Ain Shams Eng. J., 16, (12), (2025), 103804.

✉ Corresponding Author Email: *esmaates@ktu.edu.tr*

AI-Enabled Beamforming and Dynamic Spectrum Allocation for Reliable Long-Range IoT over 6G

Mohammed Alabdullah ✉, Dr. Vahid Amin-Ghafari

Iran University of Science and Technology, Computer Networks Engineering, Tehran, Iran

Abstract

Industrial environments expected in 6G will likely involve a mix of very different IIoT devices, including mobile robots such as AMRs and AGVs, alongside fixed sensors used for continuous monitoring of industrial operations. Integrating these diverse devices within the same industrial network remains challenging. Their operation depends on wireless links that can preserve reliability across longer coverage ranges while still meeting the demands of real-time control and ongoing data exchange. In practical settings, many existing scheduling and resource allocation schemes do not perform well enough, largely because they are built for more predictable network conditions than those found in dynamic industrial environments. The main issue is that they assume relatively stable conditions, while industrial networks are constantly changing due to varying traffic loads, device movement, and fluctuating channel quality. To address this challenge, this study explores the use of reinforcement learning (RL) for uplink scheduling in a conceptual 6G industrial setting. A reinforcement learning approach based on Proximal Policy Optimization (PPO) is used to decide how radio resources are shared between static sensors and mobile devices. Instead of following fixed rules, the agent is exposed to different traffic scenarios during training. This allows it to observe how congestion builds up and how different traffic types interact, gradually shaping its own scheduling strategy to keep the system operating in a stable manner. The simulation outcomes indicate that the PPO-based approach is capable of postponing the point at which system performance begins to degrade sharply, compared to a random scheduling strategy. This improvement is particularly noticeable for static sensing traffic, which achieves higher packet delivery ratios under moderate and heavy load conditions. However, as congestion intensifies, the learned policy tends to favor static devices, which leads to a noticeable drop in performance for AMR and AGV traffic. Under these conditions, an inversion behavior appears, where random scheduling can outperform PPO for mobile devices. Overall, the results highlight a clear trade-off when dealing with mixed industrial traffic types. They also underline the importance of designing scheduling mechanisms that explicitly account for mobility and multiple performance objectives. Future work can further improve these results by combining RL-based scheduling with advanced technologies such as AI-driven beamforming and digital twin systems to achieve more reliable and scalable industrial communication in emerging Industry 5.0 environments.

Keywords: 6G, Industrial IoT, Industry 5.0, Reliability

References

[1] W. Saad, M. Bennis, and M. Chen, "The Vision of 6G: A New Era of Intelligent Connectivity," IEEE Communications Magazine, vol. 61, no. 3, pp. 12–18, 2023.
[2] X. You et al., "Towards 6G Wireless Communication Networks: Vision, Enabling Technologies, and New Paradigm Shifts," Science China Information Sciences, 2023.
[3] K. Letaief, W. Chen, Y. Shi, J. Zhang, and Y.-J. A. Zhang, "The Roadmap to 6G: AI Empowered Wireless Communications," IEEE Communications Magazine, vol. 57, no. 8, pp. 84–90, 2019.

✉ Corresponding Author Email: *m.w@sudo-gate.com*

Fourier Analysis of the Tsunami Doublet of the 6 February 2023 Kahramanmaraş (Türkiye) Earthquake Using Arsuz Tide-Gage Records

Sara Taheri[1]✉, Hivda Elçi[1], Cihan Bayındır[1,2], Barış Namlı[1], Ali Rıza Alan[3], Fatih Ozaydin[4] , Azmi Ali Altintas[5]

[1] *İstanbul Technical University, Engineering Faculty, İstanbul, Türkiye*
[2] *Boğaziçi University, Engineering Faculty, İstanbul, Türkiye*
[3] *Bahçeşehir University, Engineering Faculty, İstanbul, Türkiye*
[4] *Tokyo International University, Institute for International Strategy and Emerging Technologies, Tokyo, Japan*
[5] *İstanbul University, Department of Physics, İstanbul, Türkiye*

Abstract

The 6 February 2023 Türkiye earthquake sequence, consisting of two major events at 01:17 UTC (Mw 7.7) near Pazarcık, Kahramanmaraş, and at 10:24 UTC (Mw 7.6) near Elbistan, Kahramanmaraş, provides a rare case for investigating tsunami doublet-related sea-level response in the eastern Mediterranean [1]. Although both earthquakes occurred on land, tsunami signals were recorded at coastal stations including Arsuz [2,3]. In this study, sea-level data from the Arsuz tide gage, obtained through the UNESCO monitoring system, are de-tided and divided into four time windows: pre-earthquake, post-first-earthquake, post-second-earthquake, and the full-record. Fourier spectral analysis is then applied to examine changes in spectral features, energy and dominant frequencies as in [4]. Preliminary results show that, after the first earthquake, the spectrum broadens, the spectral amplitude increases significantly, the peak frequency shifts toward higher bands, and some energy leaks into high-frequencies. After the second earthquake, a partial rightward shift and additional high-frequency fluctuations are still observed relative to the pre-event state, but both the overall spectral amplitude and the high-frequency oscillations remain weaker compared to the first event since the epicenter of the second earthquake at Elbistan lies much further to the sea. Our study contributes to understanding how successive large earthquakes may modify ongoing tsunami doublet-induced oscillations.

Keywords: 6 February 2023 Türkiye earthquake, tsunami doublet, Fourier analysis, Arsuz tide gage.

Acknowledgments

The authors acknowledge the Kandilli Observatory and Earthquake Research Institute (KOERI) for providing the earthquake source parameters.

References

[1] Boğaziçi University Kandilli Observatory and Earthquake Research Institute, *06 Şubat 2023 Ekinözü Kahramanmaraş Depremi,* http://www.koeri.boun.edu.tr/sismo/2/wp-content/uploads/2023/02/20230206_1024_KAHRAMANMARAS.pdf, Date accessed: 15 April 2026.

[2] Dogan, G.G., Guler, H.G., Guler, I., & Yalciner, A.C. (2025). Anatomy of the February 6, 2023, Eastern Mediterranean tsunami: Field observations, sea level analysis and numerical modeling. *Ocean Engineering*, 342, 123066.

[3] Medvedeva, A., Vydrin, D., Krylov, A., Shiryborova, A., Smirnova, D., Tsukanova, E., Kanoglu, U., & Medvedev, I. (2023). The Turkish tsunami of 6 February 2023 in the Northeastern Mediterranean. *Pure and Applied Geophysics, 180*(9), 3177–3193.

[4] Alan, A.R., Bayındır, C., Ozaydin, F., & Altintas, A.A. (2023). The predictability of the 30 October 2020 İzmir-Samos tsunami hydrodynamics and enhancement of its early warning time by LSTM deep learning network. *Water*, 15(23), 4195.

✉ Corresponding Author E-mail: *taherisara1380@gmail.com*

Mass Optimization of a Composite Cylindrical Skirt Structure Using Genetic Algorithm and Particle Swarm Optimization

Ekin Oktay ✉, Halit Süleyman Türkmen

Istanbul Technical University, Department of Aeronautical and Astronautical Engineering, İstanbul, Turkey

Abstract

Composite structures are widely employed in aerospace applications owing to their exceptional strength-to-weight ratio and design flexibility. The structural performance of such components is critically dependent on the fiber winding angle and ply thickness distribution, making the optimization of these parameters essential during the preliminary design phase.

This study revisits a composite cylindrical skirt optimization problem previously studied in the literature using a hybrid genetic algorithm combined with Powell's optimization routine [1]. The problem definition, including geometric properties, material parameters, loading conditions, and constraint formulations, is fully adopted from the reference study to provide a well-defined benchmark for algorithmic comparison. A standard genetic algorithm (GA) implementation is developed to minimize the structural mass of the carbon/epoxy skirt subjected to combined axial compression and aerodynamic torque, while satisfying both buckling and stress-based failure constraints. The Tsai-Wu failure criterion is employed to evaluate material failure under multiaxial stress states, and classical lamination theory is used for structural analysis [2]. Following the reference study, the thicknesses of the 0°/90° and θ°/−θ° ply groups together with the winding angle θ are treated as the design variables. Preliminary optimization results have been obtained, and validation against the reference solutions is currently underway.

Future work will extend the framework to Particle Swarm Optimization (PSO), enabling a direct comparison of metaheuristic approaches on the same benchmark problem in terms of solution quality and convergence behavior. Furthermore, a parametric study investigating the influence of varying load magnitudes on the optimum design variables is planned. Additionally, finite element analysis (FEA) will be employed to validate the CLT-based structural responses for the optimized winding configurations.

Keywords: Composite cylindrical skirt 1, genetic algorithm 2, mass optimization 3, Tsai-Wu failure criterion 4, buckling 5, filament winding 6

References

[1] Liang, C.-C., & Chen, H.-W. (2003). Optimum design of fiber-reinforced composite cylindrical skirts for solid rocket cases subjected to buckling and overstressing constraints. Composites Part B: Engineering, 34(3), 273–284. doi:10.1016/s1359-8368(02)00104-x

[2] Kaw, A. K. (1997). Mechanics of Composite Materials. Taylor & Francis Group.

✉ Corresponding Author Email: *oktaye19@itu.edu.tr*

Real-Time Optimal Control of Quadrotor Dynamics via Physics-Informed Recursive Least Squares

Nejat Tukenmez[1,2]✉, Seta Bogosyan[3,4]

[1] *Istanbul Technical University, Mechatronics Engineering Department, Istanbul, Turkiye*
[2] *Georgia Institute of Technology, The Daniel Guggenheim School of Aerospace Engineering, Atlanta, GA, US*
[3] *MEF University, Electrical and Electronic Engineering Department, Istanbul, Turkiye*
[4] *City College of New York, Computer Science Department, New York, USA*

Abstract

Traditional optimal control strategies, such as the Linear Quadratic Regulator (LQR), rely on the offline solution of the Algebraic Riccati Equation (ARE) under the assumption of a perfectly known and static plant model. However, mechatronic systems like quadrotors frequently operate in dynamic environments characterized by parametric uncertainties and external disturbances, which can invalidate offline-calculated gains. While Physics-Informed Neural Networks (PINNs) offer a framework for solving the governing Hamilton-Jacobi-Bellman (HJB) equations, their iterative training requirements often preclude real-time embedded implementation. This paper proposes a Physics-Informed Recursive Least Squares (PI-RLS) framework that achieves real-time optimal control adaptation without the computational overhead of backpropagation. By formulating the HJB equation as a physics-informed residual, we derive a closed-form recursive update law that treats the elements of the cost-to-go matrix as time-varying parameters. This approach allows the controller to minimize the optimality gap in a single step per sample, effectively functioning as a high-order disturbance observer that re-synthesizes the control law during flight. The proposed method is validated through simulations and experiments. Results demonstrate that PI-RLS converges to optimal LQR solution approximately faster than gradient-based PINNs and provides superior robustness compared to static LQR controllers. This research provides a substantial bridge between deep learning-based control and classical adaptive control.

Keywords: Adaptive Control, Real-Time Optimization, Reinforcement Learning, Quadrotor, Physics-Informed Machine Learning, Recursive Least Squares.

Acknowledgements

This work was supported by the Scientific and Technological Research Council of Türkiye (TÜBİTAK).

References

[1] Bradtke, S. (1992). Reinforcement learning applied to linear quadratic regulation. Advances in neural information processing systems, 5.
[2] Åström, K. J. (1995). Adaptive control. In Mathematical System Theory: The Influence of RE Kalman (pp. 437-450). Berlin, Heidelberg: Springer Berlin Heidelberg.
[3] Lee, T., Leok, M., & McClamroch, N. H. (2010, December). Geometric tracking control of a quadrotor UAV on SE (3). In 49th IEEE conference on decision and control (CDC) (pp. 5420-5425). IEEE.
[4] Sutton, R. S., & Barto, A. G. (1998). Reinforcement learning: An introduction (Vol. 1, No. 1, pp. 9-11). Cambridge: MIT press.
[5] Bradtke, S. J., & Barto, A. G. (1996). Linear least-squares algorithms for temporal difference learning. Machine learning, 22(1), 33-57.

✉ Corresponding Author Email: *tukenmez16@itu.edu.tr*

Solving the 3D Bin Packing Problem for Heterogeneous Vehicles Using an Empty Maximal-Spaces Based Genetic Algorithm

Oktay Yilmaz[1]✉, Ibrahim Kucukkoc[2]

[1] *ERD Information Technologies, Istanbul, Turkiye*
[2] *Balikesir University, Department of Industrial Engineering, Balikesir, Turkiye*

Abstract

In supply chain and logistics management, the optimal loading of products into distribution vehicles is one of the most critical processes directly affecting transportation costs and operational efficiency. In this context, the problem referred to as the Three-Dimensional Bin Packing Problem (3D BPP) in the literature aims to maximize the utilization of the capacity of transportation vehicles. However, the presence of multiple heterogeneous vehicles and operational constraints in real-time shipment operations makes the problem more complex.

In this study, a capacitated 3D BPP for multiple heterogeneous vehicles is addressed. The primary objective of the problem is to minimize the total unused space of the utilized vehicles or containers. To align with real-world constraints, the "Product Family Concerns" constraint is incorporated into the model [1]. Under this constraint, all loads destined for the same delivery node must be loaded into the same vehicle without being split. Since the problem is inherently an NP-Hard combinatorial optimization problem [2], it is highly challenging for traditional solution methods to reach the optimal solution in reasonable timeframes. Therefore, a novel Genetic Algorithm (GA) utilizing the "Empty Maximal-Spaces" [3] placement strategy is developed as an alternative solution method. The proposed approach has been tested on data sets of varying sizes, and the performance results have been evaluated. The computational analysis results demonstrate that the proposed genetic algorithm using the "Empty Maximal-Spaces" placement strategy produces high-quality solutions, particularly in small and medium-sized problems. In this regard, this study offers a practical, fast, and effective decision support tool aimed at increasing vehicle utilization rates in logistics and shipment management systems.

Keywords: Transportation Management Systems, 3D Bin Packing Problem, Genetic Algorithm, Empty Maximal Spaces, Product Family.

References

[1] Erbayrak, S., Özkır, V., & Yıldırım, U. M. (2021). Multi-objective 3D bin packing problem with load balance and product family concerns. *Computers & Industrial Engineering*, *159*, 107518. https://doi.org/10.1016/j.cie.2021.107518

[2] Liu, D. S., Tan, K. C., Huang, S. Y., Goh, C. K., & Ho, W. K. (2008). On solving multiobjective bin packing problems using evolutionary particle swarm optimization. *European Journal of Operational Research*, *190*(2), 357-382. https://doi.org/10.1016/j.ejor.2007.06.032

[3] Gonalves, J. F., & Resende, M. G. (2013). A biased random key genetic algorithm for 2D and 3D bin packing problems. *Int. J. Production Economics*, *145*, 500-510. https://doi.org/10.1016/j.ijpe.2013.04.019

✉ Corresponding Author Email: *oktay.yilmaz@std.yildiz.edu.tr*

Order Picking Route Optimization in Warehouses Using Virtual Node Aggregation

Oktay Yilmaz✉

ERD Information Technologies, Istanbul, Turkiye

Abstract

Order picking activities in warehouse management systems constitute one of the most critical components of total warehousing operational costs and time. Reducing the travel time of order pickers within the warehouse directly enhances operational efficiency. In this context, the optimization of order picking routes is frequently modeled as the Traveling Salesman Problem (TSP). However, in dynamic warehouse environments with high product variety and numerous picking locations, the computational times of traditional routing algorithms can become operationally unacceptable.

In this study, a novel approach based on virtual node aggregation is proposed to optimize order picking routes in warehouses. In the proposed method, opposite racks and adjacent picking locations within the warehouse are clustered based on their geographical coordinates and consolidated under a single virtual node. The distances between nodes are determined by identifying the shortest paths among available alternatives and predefining the specific aisles to be traversed [1]. Instead of sequencing all individual points, the route optimization algorithm operates by sequencing only these active virtual nodes. Consequently, the problem dimension is significantly reduced, and the algorithmic complexity is minimized.

The developed approach has been tested on a realistic warehouse layout and compared with traditional order picking heuristics widely used in the literature (S-Shape, Return, and Combined/Composite strategies) [2]. The computational analysis results demonstrate that the proposed method not only significantly improves order picking times compared to these traditional strategies but also substantially shortens the solution time. In this regard, this study offers a fast and effective decision support tool, particularly for real-time warehouse operations that require immediate order picking planning.

Keywords: Warehouse Management Systems, Order Picking, Route Optimization, Virtual node aggregation.

References

[1] Shetty, N., Sah, B. & Chung, S.H. Route optimization for warehouse order picking operations via vehicle routing and simulation. SN Appl. Sci. 2, 311 (2020). https://doi.org/10.1007/s42452-020-2076-x

[2] Moeller, K. (2011). Increasing warehouse order picking performance by sequence optimization. Procedia-Social and Behavioral Sciences, 20, 177-185. https://doi.org/10.1016/j.sbspro.2011.08.023

✉ Corresponding Author Email: *oktay.yilmaz@std.yildiz.edu.tr*

Time-Periodic Solutions for Coating Flow on A Rotating Elliptic Cylinder

Vinícius Silva[1]✉, André Lopes[1,2]

[1] *University of Brasília,Mechanical Engineering Department, Brasília, Brazil*
[2] *University of Brasília,Mathematics Department, Brasília, Brazil*

Abstract

The present work addresses the coating of an elliptic cylinder by a viscous liquid film. This configuration is motivated by situations in which a liquid layer must remain attached to a curved solid surface whose curvature is not constant. Unlike the classical circular-cylinder geometry, the elliptic boundary introduces regions with different local curvature, which changes the way gravity, capillarity, viscous forces, and wall motion act along the perimeter. Because of this geometric variation, even simple operating conditions may produce non-uniform film distributions. The main goal of this study is to obtain periodic solutions for the film thickness around the closed elliptic contour. The problem is formulated using coordinates attached to the solid boundary, allowing the effects of curvature and local geometric stretching to appear naturally in the governing equations. For sufficiently thin films, the model is reduced to a lubrication-type equation describing the free-surface profile along the cylinder. Periodicity is imposed as a fundamental condition, since the liquid layer must match itself after one complete revolution around the body. Computational results are presented for selected representative cases in order to examine how the elliptic aspect ratio and the orientation of the cylinder affect the coating pattern. The solutions show that the non-uniform curvature of the ellipse can intensify variations in the film thickness, creating regions where the liquid accumulates and others where the layer becomes thinner. These effects are especially noticeable near portions of the boundary where the curvature changes more rapidly. The results contribute to the understanding of coating flows over non-circular bodies and may be useful as reference cases for future analytical or asymptotic studies of thin films on curved geometries.

Keywords: Coating flow, elliptic cylinder, thin film, periodic solutions, free-surface flow

References

[1] Leal L.G., Advanced Transport Phenomena: Fluid Mechanics and Convective Transport Processes, Cambridge University Press, Cambridge, UK, 2007.
[2] Oron A., Davis S.H., and Bankoff S.G., Long-scale evolution of thin liquid films, Rev. Mod. Phys., 69(3): 931--980, 1997.
[3] White F.M., Viscous Fluid Flow, McGraw-Hill, New York, USA, 2006.

✉ Corresponding Author Email: *viniciuscoutinho04@gmail.com*

Cardinality Constrained Risk Parity on a Sharpe Filtered Subset of the BIST 100 Index

Çağrı Latifoğlu✉

Consultkitapp LTD, Istanbul, Turkiye

Abstract

Risk parity allocates capital so that each asset contributes equally to portfolio risk, thereby achieving diversification without relying on expected return estimates. We enhance this approach by (i) pre screening assets on the basis of their historical Sharpe ratio and (ii) imposing a cardinality constraint that limits the number of securities that may receive non zero weight. The resulting optimisation problem is a mixed integer conic program that enforces equal risk contribution among the selected assets (Anis & Kwon, 2022). Empirical results obtained from the full BIST 100 sample show that the proposed Sharpe screened, cardinality constrained risk parity strategy delivers a substantial improvement in risk adjusted performance relative to the classical risk parity benchmark. Detailed numerical findings will be presented in the conference talk.

Keywords: Risk parity, BIST 100, mixed integer conic program

References

[1] Anis, Hassan T, and Roy H Kwon. 2022. "Cardinality-Constrained Risk Parity Portfolios." European Journal of Operational Research 302 (1): 392–402.
[2] Maillard, Sébastien, Thierry Roncalli, and Jérôme Teïletche. 2010. "The Properties of Equally Weighted Risk Contribution Portfolios." Journal of Portfolio Management 36 (4): 60.
[3] Qian, Edward et al. 2005. "Risk Parity Portfolios: Efficient Portfolios Through True Diversification." Panagora Asset Management 1 (1): 1–10.

✉ Corresponding Author Email: *cagrilatifoglu@consultkit.app*

Lexicographic approach for multi-objective humanitarian allocation problem

İlknur Tükenmez✉

Bursa Technical University, Industrial Engineering Department, Bursa, Türkiye

Abstract

As the frequency of global disasters continues to rise, optimizing post-disaster humanitarian aid problem has become increasingly critical. The post-disaster vehicle allocation problem is critically important because it ensures that emergency relief supplies are delivered to affected areas as quickly and efficiently as possible. In the initial phase after a disaster, the amount of available aid is often lower than the total demand. While limited capacity aid is distributed, the demand of every region may not be fully met. Therefore, considering both equity and effectiveness during aid distribution is essential to achieve a fair and efficient allocation of resources. In the literature, [1] studied post disaster vehicle routing problem. Unsatisfied demand and total travel time is minimized. Bi-objective model is solved by epsilon constraint method, and branch and price algorithms. Similarly, [2] used deterministic parameter to solve humanitarian problem. [3] are interested in humanitarian location-routing problem under efficiency, efficacy and equity perspectives. However, certain areas particularly those with higher population densities or severe damage require special prioritization due to their heightened vulnerability. To address this complexity, a multi objective model is proposed that seeks to minimize total route time and ineffectiveness and maximize the met prioritized demand. Since the objective functions do not have equal importance, the lexicographic approach was employed. In this study, the multi-objective model was solved with lexicographic approach, and results were obtained accordingly.

Keywords: Lexicographic Approach, Humanitarian aid, Vehicle allocation problem

Acknowledgements

This study was funded by The Scientific and Technological Research Council of Turkey (TUBITAK) with entitled 2219 project number.

References

[1] Mostajabdaveh, M., Salman, F. S., and Gutjahr, W. J. (2025). A branch-and-price algorithm for fast and equitable last-mile relief aid distribution. European Journal of Operational Research.

[2] Gutjahr, W. J., Fischer, S., (2018), Equity and deprivation costs in humanitarian logistics, European Journal of Operational Research 270, 185-197.

[3] Huang, M., Smilowitz, K., and Balcik, B. (2012). Models for relief routing: Equity, efficiency and efficacy. Transportation research part E: logistics and transportation review, 48(1):2–18.

✉ Corresponding Author Email: *ilknur.tukenmez@btu.edu.tr*

On Oresme Sequence Spaces

Furkan Mert Gümüş ✉, Serkan Demiriz

Tokat Gaziosmanpaşa University, Department of Mathematics, Tokat, Turkey

Abstract

The history of Oresme numbers is inextricably linked to the work of the 14th century French polymath Nicole Oresme, one of the most influential thinkers of the Late Middle Ages. These numbers represent a critical turning point in the history of mathematics, particularly in terms of the sum of infinite series and the theory of sequences. These number sequences were first used in sequence spaces theory in 2025. As a continuation of that study, in this study it is introduced the regular Oresme matrix operator which is obtained by using Oresme numbers and examined sequence spaces described as the domain of this matrix in the space of $p-$ summable sequences for $1 \leq p \leq \infty$. After that, it investigated some properties and inclusion relations, established the Schauder basis, and stated $\alpha-, \beta-, and\ \gamma-$duals of the aforementioned spaces. Additionally, it is characterized by the matrix classes from newly described spaces to classical sequence spaces.

Keywords: Duals, Matrix transformations, Oresme numbers, Sequence spaces

References

[1] Erdem, S., Demiriz, S., (2025) Oresme Numbers and Associated BK-Sequence Spaces, Iranian Journal of Science, 49, 725-732.
[2] Demiriz, S., Erdem, S., (2024) Mersenne Matrix Operator and Its Application in $p-$Summable Sequence Space, Communications in Advanced Mathematical Sciences, 7(1), 42-55.
[3] Soykan, Y., (2021) Generalized Oresme Numbers, Earthline J. Math. Sci., 7(2),333-367.
[4] Başar, F., (2011) Summability Theory and Its Applications, Bentham Science Publishers, İstanbul

✉ Corresponding Author Email: *mert.gumuus@hotmail.com*

Physics-Informed Neural Networks for Periodic Sturm-Liouville Eigenvalue Problems

Seza Dinibutun✉

International University of Science and Technology in Kuwait, Department of Mathematics and Natural Sciences, Ardiya 92400, Kuwait

Abstract

Periodic Sturm–Liouville problems appear in many areas of physics and engineering, including quantum mechanics, wave propagation, and vibration analysis [1]. In this study, Physics-Informed Neural Networks (PINNs) [2,3] are used to compute periodic eigenvalues and eigenfunctions for a Sturm–Liouville problem. The governing differential equation and periodic boundary conditions are incorporated directly into the loss function, allowing the solution to be learned without the use of labeled training data.

A PINN model is developed to approximate the lowest eigenvalue and the corresponding eigenfunction for the periodic Sturm–Liouville problem with the potential $q(x) = 2\cos(2x)$. The predicted eigenvalue ($\lambda_{\text{PINN}} \approx 1.8591$) is very close to the reference value obtained from classical numerical methods [4]. The computed eigenfunction satisfies the periodic boundary conditions and shows the expected oscillatory behavior, supported by numerical evaluation and graphical comparison.

The results indicate that PINNs can be used as an alternative approach for approximating eigenpairs of periodic Sturm–Liouville problems. The study also shows the potential of physics-informed neural network methods for spectral problems arising in physics and engineering.

Keywords: Physics-Informed Neural Networks (PINNs), Sturm–Liouville Problems, Periodic Boundary Conditions, Eigenvalue Problems, Spectral Problems

References

[1] Eastham, M. S. P. (1973). The Theory of Periodic Differential Equations, Scottish Academic Press, Edinburgh.

[2] Raissi, M., Perdikaris, P., and Karniadakis, G. E. (2019). Physics-informed neural networks: A deep learning framework for solving forward and inverse problems involving nonlinear partial differential equations, Journal of Computational Physics, 378, 686-707.

[3] Jin, H., Mattheakis, M., and Protopapas, P. (2022). Physics-Informed Neural Networks for Quantum Eigenvalue Problems, arXiv preprint, arXiv:2203.00451.

[4] Dinibutun, S. (2021). An estimation of the eigenfunctions of periodic Sturm-Liouville problems, Arab Journal of Basic and Applied Sciences, 28(1), 107-112.

✉ Corresponding Author Email: *seza.dinibutun@iuk.edu.kw*

Reconstruction of Hydraulic Transients in Surge Tanks and Pipelines via Compressive Sensing and Discrete Cosine Transform

Ali Rıza Alan[1], Barış Namlı[2], Cihan Bayındır[2,3,4]✉, Sara Taheri[2]

[1] *Bahçeşehir University, Engineering Faculty, İstanbul, Türkiye*
[2] *İstanbul Technical University, Engineering Faculty, İstanbul, Türkiye*
[3] *İstanbul Technical University, Disaster Management Institute, Earthquake Engineering Program, İstanbul, Türkiye*
[4] *Boğaziçi University, Engineering Faculty, İstanbul, Türkiye*

Abstract

Monitoring hydraulic transients is vital for the structural integrity of water distribution and hydroelectric systems [1-3]. However, capturing these oscillations often requires high-density sampling that strains sensor battery life and data bandwidth. This paper simulates the dynamics of an undamped surge tank using a rigid water column model governed by coupled ordinary differential equations (ODEs). The set of ODEs describing the surge tank and pipe dynamics is solved by MATLAB ODE integrator. By applying the discrete cosine transform (DCT) as one of the possible orthogonal transform candidates, the oscillations in the tank and pipeline system are projected into a sparse frequency-based representation [4]. The framework employs a compressive sampling (CS) strategy, selecting a randomized subset of the simulated time-series data [5-6]. Signal recovery is achieved through a pseudo-inverse reconstruction with hard thresholding, which effectively filters out low-magnitude noise and focuses on the dominant oscillatory modes. The results demonstrate that the physical signal can be recovered with high fidelity, providing a methodology to reduce the energy consumption of remote sensing nodes in water infrastructure without sacrificing diagnostic accuracy. Also, control of the surge tank and pipes can be performed via the CS-based methodology introduced in our paper.

Keywords: Surge tanks, pipe network, compressive sensing, flow throttling.

References

[1] Houghtalen, R.J., Akan, A.O. & Hwang, N.H. (2016). Fundamentals of Hydraulic Engineering Systems. Pearson.
[2] Chaudhry, M.H. (2014). Applied Hydraulic Transients. Springer.
[3] Hart, D., Rodriguez, J.S., Burkhardt, J., Borchers, B., Laird, C., Murray, R., Klise, K. & Haxton, T. (2019). Quantifying Hydraulic and Water Quality Uncertainty to Inform Sampling of Drinking Water Distribution Systems. Journal of Water Resources Planning and Management, 145(3).
[4] Ahmed, N., Natarajan, T. & Rao, K.R. (1974). Discrete Cosine Transform. IEEE Transactions on Computers, C-23(1), 90–93.
[5] Candes, E.J. & Wakin, M.B. (2008). An Introduction to Compressive Sampling. IEEE Signal Processing Magazine, 25(2), 21–30.
[6] Donoho, D.L. (2006). Compressed sensing. IEEE Transactions on Information Theory, 52(4), 1289–1306.

✉ Corresponding Author Email: *cbayindir@itu.edu.tr*

Neural Network-Based Computational Solutions of the Kairat-II-X Equation

Fatma Nur Kaya Sağlam[1]✉, Muhammed Ishfaq Khan[2]

[1] *Cappadocia University, Department of Information Security Technology, Nevşehir, Türkiye*
[2] *Hohai University, College of Mechanics and Engineering Science, Nonjing, China*

Abstract

In this study, we investigate the nonlinear wave dynamics of the Kairat-II-X equation using a neural network-based analytical framework. This equation arises in the explanation of nonlinear dispersive wave propagation phenomena, which appear in different areas of mathematical physics and applied science. The exact analytical solutions are generated by means of the Riccati mapping neural network method, that can be used to obtain various nonlinear wave structures. The obtained families of solutions contain hyperbolic, trigonometric and rational wave frameworks related to different parameter configurations of the governing model. The validity of all the obtained solutions is verified by direct substitution of the corresponding solutions into the original nonlinear evolution equation. The physical properties and propagation characteristics of the generated wave structures are also investigated. The results obtained show that the proposed neural-network based analytical procedure offers an effective structure to investigate nonlinear evolution equations with complex wave characteristics. In addition, the present study can be generalized in future works to higher-dimensional structures, fractional nonlinear systems, and physics-informed deep learning algorithms for nonlinear wave propagation phenomena.

Keywords: the generalized Riccati equation mapping method neural network, Kairat-II-X equation, soliton solutions

✉ Corresponding Author Email: *fatma.saglam@kapadokya.edu.tr*

Parameter Sensitivity Analysis of an Online Gaming Addiction Model

Elif İlkin Ersoy[1], Demet Ersoy Özdek[2]✉, Sevin Gümgüm[2]

[1] *Department of Mathematics, Ege University, Izmir, Turkey*
[2] *Department of Mathematics, Izmir University of Economics, Izmir, Turkey*

Abstract

This study investigates the interaction dynamics of online gaming addiction in society and focuses on parameter sensitivity analysis of the model. Using a similar approach to infectious disease modeling, the addiction dynamics are described as a five-compartment system of nonlinear ordinary differential equations. In addition, the model includes a psychological awareness parameter to examine the effect of individual awareness on the transmission dynamics. The mathematical model is numerically solved to obtain approximate solutions using a collocation method. The graphical results illustrate how the addiction spreads among the five compartments, while the comparison of the numerical results with the fourth-order Runge-Kutta method and Mathematica's default solver is made to verify that the results are in good agreement. Moreover, the residual error analysis is conducted to evaluate the validity and the accuracy of the numerical solutions. To determine the impacts of the model parameters on the transmission dynamics and highlight the most influential parameter affecting long-term behaviour of the system, parameter sensitivity analysis is performed in detail.

Keywords: Online Gaming Addiction, Approximate Solutions, Parameter Sensitivity Analysis.

References

[1] Soni, M., Sharma, R. K., & Sharma, S. (2024). Applying the PUARL mathematical model: Psychological insights for restricting gaming and internet addiction. Journal of the Korean Society of Mathematics Education Series B: Pure and Applied Mathematics, 31(4), 365–386. https://doi.org/10.7468/jksmeb.2024.31.4.365

[2] Brauer, F., Castillo-Chavez, C., & Feng, Z. (2019). Mathematical Models in Epidemiology. Springer, New York.

[3] Kuss, D. J., & Griffiths, M. D. (2012). Internet gaming addiction: A systematic review of empirical research. International Journal of Mental Health and Addiction, 10(2), 278-296.

[4] Side, S., Saman, A., Ramadhan, N. R., & Sidjara, S. (2021). The accuracy of the RK-4 and RK-5 technique as a numerical solution to the SEIRS model of online game addiction on mathematics students. Journal of Physics: Conference Series, 2123(1), 012005. https://doi.org/10.1088/1742-6596/2123/1/012005

[5] Darvesh, N., Radhakrishnan, A., Lachance, C.C., Nincic, V., Sharpe, J.P., Ghassemi, M., Strauts, S.E., & Tricco, A.C. (2020). Exploring the prevalence of gaming disorder and Internet gaming disorder: a rapid scoping review. Systematics Reviews 9, 68. https://doi.org/10.1186/s13643-020-01329-2

✉ Corresponding Author Email: *demet.ersoy@ieu.edu.tr*

A Multilevel ID-Tucker-FFT Acceleration Scheme for Volume Integral Equation Solvers in 2D Scattering Problems

Arda Yalcinkaya[1]✉, Xiaofan Jia[1], Yang Liu[2], and Abdulkadir C. Yucel[1]

[1] *Nanyang Technological University, 639798, Singapore*
[2] *Lawrence Berkeley National Laboratory, Berkeley, CA 94720, USA*

Abstract

Volume integral equation (VIE) solvers for two-dimensional (2D) TM_z scattering problems are used extensively in complex optical system modeling, channel characterization, and remote sensing applications. These solvers operate on dense matrices representing discretized free-space Green's functions and are often accelerated by the fast Fourier transforms (FFTs). While FFT-accelerated VIE solvers exhibit $O(N \log N)$ computation and $O(N)$ memory requirement, their efficiency deteriorates when applied to sparse and/or multiscale geometrical structures due to the need to use a uniform grid in the entire computational domain. Matrix decomposition-based methods, including singular value decomposition (SVD) (S. Kapur and D. E. Long, *IEEE Computational Science and Engineering*, 5(4), 60-67, 1998), adaptive cross approximation (K. Zhao, et al., *IEEE Trans. Electromagn. Compat.*, 47(4), 763-773, 2005), and butterfly compression (S.B. Sayed., et al., *IEEE Trans Antennas Propagat.*, 70(5), 3549-3559, 2021), offer more flexibility in handling sparse and multiscale structures. These matrix decomposition-based schemes allow compressing low-rank off-diagonal blocks in the system matrix and performing the matrix-vector multiplications via compressed blocks during the iterative or direct solution of the linear system of equations. That said, tensor decomposition techniques can achieve even higher compression ratios and improved computational efficiency compared to conventional matrix-based approaches due to their ability to exploit the redundancy of degrees of freedom in higher-dimensional spaces. So far, tensor decomposition schemes, particularly tensor train-based ones, have been applied to the acceleration of various 2D static, quasi-static, and TM_z scattering analyses (C. Nguyen, et al., *IEEE Trans. Microw. Theory Techn.*, 73(12), 2025). On the other hand, the ones leveraging Tucker decomposition have been applied to the acceleration of various 3D static and quasi-static analyses (X. Jia, et al., "Tucker-SVD-FFT-accelerated solution of volume integral equation for magneto-quasi-static analysis of voxelized geometries," in *Proc. Int. Applied Comp. EM Society Symp.* 2024). To the best of our knowledge, no prior study has proposed a multilevel Tucker-decomposition-based acceleration framework and applied it to high-frequency electromagnetic scattering problems.

In this study, we propose a multilevel ID-Tucker-FFT accelerated VIE solver for high-frequency 2D scattering problems, in which the computational domain is recursively partitioned into a binary hierarchy of square boxes down to a fixed FFT-friendly leaf size. In the proposed scheme, interactions between touching leaf boxes are evaluated by local circulant FFTs, while admissible far interactions generated during recursive near-pair refinement are represented by reusable ID-Tucker tensors. Each far box-pair block is viewed as a four-dimensional tensor with two observation-coordinate modes and two source-coordinate modes. Mode bases are constructed by matrix-free interpolative decomposition using geometry-aware proxy columns and rank-revealing QR, and the resulting small ID-Tucker core is refined by a higher-order singular value decomposition (HOSVD) step. The compressed factors and local FFT kernels are then used directly in the matrix-vector product without assembling the dense VIE matrix. Preliminary results show that the multilevel scheme maintained matrix-vector errors on the order of the prescribed tolerance. For a geometry with 4 million unknowns, the multilevel operator required 5.35 MB, compared with 108.58 MB for the single-level compressed operator and 256 MB for the FFT kernel, giving 20.3 × and 47.8 × storage reductions, respectively. Its setup time was 4.71 s versus 164.19 s for the single-level ID-Tucker operator, a 34.9 × reduction, while its matrix-vector time reduced, 3.56 s versus 2.64 s. These results show that the multilevel ID-Tucker-FFT formulation can substantially reduce compressed-operator storage and setup cost while preserving accuracy relative to the FFT reference and maintaining practical matrix-vector times.

Keywords: Interpolative Decomposition (ID), FFT, Tucker Decomposition, Tensor Techniques

✉ Corresponding Author Email: e240224@e.ntu.edu.sg

Dual Reciprocity BEM Solutions of Nonlinear Wave Equations in Cracked Regions

Münevver Tezer-Sezgin[1]✉, Pelin Şenel[2]

[1] *Middle East Technical University, Mathematics Department, Ankara, Türkiye*
[2] *Karadeniz Technical University, Mathematics Department, Trabzon, Türkiye*

Abstract

This study presents the dual reciprocity boundary elements method (DRBEM) for solving linear and nonlinear wave equations in two-dimensional cracked regions. The DRBEM solves the Poisson's equation of the form $\nabla^2 u = F\left(x, y, t, G(u), \frac{\partial^2 u}{\partial t^2}, f(x, y, t)\right)$ with the fundamental solution of the Laplace equation where the functional F, nonlinear function G and linear function f are specified. Time derivative of the solution in the resulting BEM matrix-vector equation is discretized using Houbolt iteration scheme which is implicit and unconditionally stable backward type finite difference formula with error $O(\Delta t^2)$. The nonlinearity $G(u)$ is also advanced iteratively inside the time integration scheme. The advantage of using DRBEM in multiply connected regions is made use of to treat the cracked regions easily. The DRBEM is computationally efficient due to its boundary only nature which results in small sized system of equations compared to domain discretization methods. Linear and nonlinear wave equation test problems on cracked domains are solved with acceptable accuracy and efficiency in terms of relative errors using L_2 norms, and the profiles of the solution at the transient levels capture the physical behavior of scaler wave equation.

Keywords: Cracked region, wave equation, DRBEM.

References

[1] Partridge, P.W., Brebbia, C.A., & Wrobel, L.C. (1991). The Dual Reciprocity Boundary Element Method. Computational Mechanics Publications, Southampton.
[2] Loeffler, C.F., & Mansur, W.J. (1987). Analysis of time intagration schemes for BEM applications to transient wave propagation problem, BETECH 87, Computational Mechanics Publications Southampton.
[3] Haghighi, D., Abbasbandy, S., & Shivanian, E. (2023). Study of the fragile points method for solving two-dimensional linear and nonlinear wave equations on complex and cracked domains. Engineering Analysis with Boundary Elements, 146, 44-55.

✉ Corresponding Author Email: *munt@metu.edu.tr*

Numerical Solutions of 3D MHD Equations using Differential Quadrature Method

Selçuk Han Aydin✉

Karadeniz Technical University, Department of Mathematics, Trabzon, TÜRKİYE

Abstract

It is known that the Differential Quadrature Method (DQM) is well known and mostly used numerical scheme due to the it's simple formulation and computational efficiency. Even the method is firstly proposed by Bellman for the rapid solution of nonlinear partial differential equations using polynomial based approximation, many authors considered and developed the different version of the method such as Chebyshev-Gauss-Lobatto points approximation, Fourier series expansion based approximation, cubic-modified cubic-quadratic-quartic B-spline based approximations (and some others) in order to simulate the many problems in engineering and physical sciences. In the first part of this study. we compared some of well-known these approaches in terms of L2 norm and maximum norm over the different test problems having exact solutions. Then we extended these numerical schemes in order to obtain the approximated solution of both 2D and 3D MagnetoHydroDynamic (MHD) duct equations defined on square and cubic domains, respectively. Obtained solutions are displayed in terms of a table and figures, and compared with the previous literature results.

Keywords: DQM, MHD, 3D

Acknowledgements

The author wishes to thank Prof. Dr. M. Tezer-Sezgin for her valuable support and experience.

References

[1] Bellman, R., Kashef, B.G., & Casti, J. (1972). Differential quadrature: a tecnique for the rapid solution of nonlinear differential equations, Journal of Computational Physics, 10, 40–52.
[2] Bellman, R., Kashef, B., Lee, E.S., & Vasudevan, R. (1975). Differential Quadrature and Splines, Computers and Mathematics with Applications, Pergamon, Oxford, 1(3,4), 371–376.
[3] Chang, S. (2000). Differential Quadrature and Its Application in Engineering, Springer-Verlag, London.
[4] Tezer-Sezgin, M. (2004). Solution of magnetohydrodynamic flow in a rectangular duct by differential quadrature method, Computers & Fluids, 33(4), 533–547.
[5] Meirikim, P., & Roshan, T. (2006). A local differential quadrature method for the generalized nonlinear Schrödinger (GNLS) equation, An International Journal of Optimization and Control: Theories & Applications, 14(4), 391–403.
[6] Korkmaz, A., & Dağ, İ. (2012). Cubic B-spline differential quadrature methods for the advection-diffusion equation, International Journal of Numerical Methods for Heat & Fluid Flow, 22(8), 1021–1036.
[7] Geet, A., & Brajesh, K.S. (2013). Numerical solution of Burgers' equation with modified cubic B-spline differential quadrature method, Applied Mathematics and Computation, 224, 166–177.
[8] Aydin, S.H. (2022). Stabilized solution of the 3-D MHD flow problem with FEM–BEM coupling
[9] approach, Engineering Analysis with Boundary Elements, 140, 519–530.
[10] Aydin, S.H., & Erdoğan, M.C. (2023). Stabilization in 3-D FEM and solution of the MHD equations, Mathematical Methods in the Applied Sciences, 46(12), 13395–13410.

✉ Corresponding Author Email: *shaydin@ktu.edu.tr*

Strong Convergence of a Regularized Inertial Projection Method for Variational Inequality Problems

Mohd Aftab Alam✉, Syed Shakaib Irfan

Department of Mathematics, Aligarh Muslim University, Aligarh, 202002, India

Abstract

In this work, we investigate a bilevel variational inequality problem in real Hilbert spaces, where the feasible set is characterized as the solution set of another variational inequality problem. To address this problem, we introduce an effective inertial projection-contraction algorithm under monotonicity and strong monotonicity assumptions on the associated operators. The proposed scheme involves only a single projection at each iteration and employs an inertial technique to enhance the convergence speed. Under appropriate assumptions on the control parameters, we establish the strong convergence of the generated sequence to the unique solution of the considered problem. Finally, a numerical example supported by graph is presented to illustrate and validate the theoretical findings.

Keywords: convergence, solution, variational inequality, monotone, Lipschitz continuous

References

[1] Kinderlehrer, D., and Stampacchia, G. (2000). An introduction to variational inequalities and their applications. Society for Industrial and Applied Mathematics.
[2] Korpelevich, G. M. (1976). The extragradient method for finding saddle points and other problems. Matecon, 12, 747-756.
[3] He, B. (1997). A class of projection and contraction methods for monotone variational inequalities. Applied mathematics and optimization, 35(1).
[4] Sun, D. (1996). A class of iterative methods for solving nonlinear projection equations. Journal of Optimization Theory and Applications, 91(1), 123-140.
[5] Van Hieu, D., and Moudafi, A. (2021). Regularization projection method for solving bilevel variational inequality problem. Optimization Letters, 15(1), 205-229.
[6] Dong, Q. L., Gibali, A., Jiang, D., and Ke, S. H. (2018). Convergence of projection and contraction algorithms with outer perturbations and their applications to sparse signals recovery. Journal of Fixed Point Theory and Applications, 20(1), 16.
[7] Van Hieu, D., Cho, Y. J., Quy, P. K., and Ha, N. H. An effective iterative projection method for variational inequalities in Hilbert spaces. Soft Computing 26, 19 (2022), 10207-10221.

✉ Corresponding Author Email: *gi3820@myamu.ac.in*

Coupled Fundamental Solution of 3D MHD Equations and the Method of Meshless Fundamental Solution Application

Selçuk Han Aydin✉, Shokoufeh Ghezeljeh

Karadeniz Technical University, Department of Mathematics, Trabzon, Türkiye

Abstract

Magnetohydrodynamic (MHD) equations are coupled equations arising in many engineering and physical applications involving electrically conducting fluids under magnetic fields. Due to the coupled structure of the equations and the convection-dominated behavior at high Hartmann numbers, the numerical solution of MHD problems is computationally challenging, especially for three-dimensional problems. In this study, the Method of Fundamental Solutions (MFS), which is a purely meshless numerical scheme, is used to solve the steady three-dimensional MHD duct flow equations under an external oblique magnetic field. This formulation is based on the coupled fundamental solution matrix derived for the convection–diffusion type MHD equations. The velocity and induced magnetic field variables are approximated by linear combinations of coupled fundamental solutions, while the virtual source points are placed outside the physical domain to satisfy the boundary conditions. The proposed numerical scheme is applied to 3D MHD duct flow problems defined on cubic domains under different problem parameters. The obtained solutions are presented in terms of tables and figures and compared with the results available in the literature.

Keywords: Coupled Fundamental Solution, MHD, Meshless Method, 3D

Acknowledgements

The author wishes to thank Prof. Dr. M. Tezer-Sezgin for her valuable support and experience.

References

[1] Sherclif, J.A. (1965). A Textbook of Magnetohydrodynamics, Pergamon Press, Oxford.
[2] Dragoş, L. (1975) Magnetofluid Dynamics, Abacus Press.
[3] Hartmann, J., (1937) Theory of the laminar flow of an electrically conductive liquid in a homogeneous magnetic fieleld, K. Dan. Vidensk. Selsk. Mat. Fys. Medd., 15(6) , 1-28.
[4] Bozkaya, C., & Tezer-Sezgin, M. (2007). Fundamental solution for coupled magnetohydrodynamic flow equations, Journal of Computational and Applied Mathematics, 203, 125–144.
[5] Bin-Mohsin, B., & Lesnic, D. (2011). The method of fundamental solutions for Helmholtz-type equations in composite materials, Computers and Mathematics with Applications, 62, 4377–4390.
[6] Liu, S., Li, P.W., Fan, C.M., & Gu, Y. (2021). Localized method of fundamental solutions for two- and three-dimensional transient convection-diffusion-reaction equations, Engineering Analysis with Boundary Elements, 124, 237–244.
[7] Aydin, S.H. (2022). Stabilized solution of the 3-D MHD flow problem with FEM–BEM coupling approach, Engineering Analysis with Boundary Elements, 140, 519–530.
[8] Aydin, S.H., & Erdoğan, M.C. (2023). Stabilization in 3-D FEM and solution of the MHD equations, Mathematical Methods in the Applied Sciences, 46(12), 13395–13410.

✉ Corresponding Author Email: *shaydin@ktu.edu.tr*

Physics-Informed Neural Network Surrogate Modelling for Real-Time Prediction of Rain-Induced Leading-Edge Erosion in Offshore Wind Turbine Blades

Hamid Orhun Tur ✉

Balikesir University, Department of Mechanical Engineering, Balikesir, Türkiye

Abstract

Rain-induced leading-edge erosion (LEE) is a major concern which is capable of causing failure of modern offshore wind turbines that run at high rotational speeds. High-velocity raindrop impacts on the leading edge damages the protective coating, leading to aerodynamic degradation, higher maintenance costs, and reduced blade service lifetime. A Physics-Informed Neural Network (PINN)-based surrogate model is developed in this paper to facilitate swift and trustworthy prediction of rain-induced erosion in wind turbine blades. The model is trained on a high-fidelity dataset of 51 CFD simulations using Euler-Lagrange and Frozen-Flow techniques, parameterized by freestream velocity (60, 140 m/s), angle of attack (0, 12°), and droplet diameter (1, 3 mm). To keep the model physically consistent, physics-based constraining rules extracted from the Finnie erosion model and kinetic energy principles are directly incorporated into the loss function of the PINN architecture. Validation on an unseen test dataset yields a R2 of 0.996 and a Mean Absolute Percentage Error (MAPE) of 3.53%. Furthermore, computation time drops from hours (for conventional CFD) to milliseconds, representing a speed-up factor of 106. According to the sensitivity analysis, freestream velocity is the major factor determining the erosion phenomenon, explaining more than 80% of the overall variance, followed by droplet diameter, while the angle of attack has the least influence on maximum erosion intensity. The PINN model developed here is incorporated into a Digital Twin framework to generate erosion-based safe operating envelope maps and to predict long-term cumulative damage by linking Weibull wind distributions. This paper presents an approach that is both computationally efficient and physically consistent, serving as a decision-support tool for real-time erosion monitoring, predictive maintenance scheduling, and operational optimization in offshore wind turbines.

Keywords: Physics-informed learning, PINNs, Rain-induced erosion, Predictive maintenance, Digital twin

References

[1] Wen, Y., Wu, J., Lin, P., & Low, Y.M. (2025). The role of offshore wind and solar PV resources in global low-carbon transition. Science Advances, 11(43), eadx5580.
[2] Cacciuttolo, C., Navarrete, M., & Cano, D. (2025). Advances, progress, and future directions of renewable wind energy in Brazil (2000–2025–2050). Applied Sciences, 15(10), 5646.
[3] Kashyap, S., Saha, N., & Jiang, Z. (2026). Parametric scoring framework for site selection of floating offshore wind farm in India. Journal of Offshore Mechanics and Arctic Engineering, 148(3), 032001.
[4] Zhang, J., Xu, D., Wu, D., Huang, X., & Wen, C. (2025). Impact of rotor size and axial spacing on the aerodynamic performance and power generation of offshore floating dual-rotor wind turbines. Ocean Engineering, 341, 122820.
[5] Chen, P., & Chen, B. (2023). Influence of the blade size on the dynamic characteristic damage identification of wind turbine blades. Nonlinear Engineering, 12(1), 20220261.
[6] Mishnaevsky Jr, L., Hasager, C.B., Bak, C., Tilg, A.M., Bech, J.I., Rad, S.D., & Fæster, S. (2021). Leading edge erosion of wind turbine blades: Understanding, prevention and protection. Renewable Energy, 169, 953–969.
[7] Mishnaevsky Jr, L. (2022). Root causes and mechanisms of failure of wind turbine blades: Overview. Materials, 15(9), 2959.

✉ Corresponding Author Email: *pklemchsldb6@gmail.com*

Optimizer Plugger and NoiseLayer: Elegant way of Deep Learning

Musa Sina Ertuğrul[1]✉, Reha Yapali[2], Abdulkadir Taşdelen[3], Ali Konuralp[4]

[1] *Manisa Celal Bayar University, Graduate School, Manisa, Türkiye*
[2] *Muş Alparslan University, Department of Mathematics, Muş, Türkiye*
[3] *Ankara Yıldırım Beyazıt University, Computer Science Department, Ankara, Türkiye*
[4] *Manisa Celal Bayar University, Department of Mathematics, Manisa, Türkiye*

Abstract

This study leverages the performance of deep learning through adaptive, drop-in algorithms. We propose two novel methods, namely NoiseLayer and Optimizer Plugger, designed as seamless replacements for standard literature components. The NoiseLayer calculates the noise according to the Gaussian noise and scales it with the entropy of the input, so the noise is adaptive. The adaptive noise feature fits various domains, from computer vision to natural language processing (NLP). The current noise calculations mostly require a sensitive tunable parameter that leads us to fewer outcomes. This problem can be seen in language tasks perfectly. Also, the noise algorithms vary according to their purposes, and this variation led us to the long tuning sessions. The tuning sessions drain the hardware resources of the researchers for decades. However, the proposed NoiseLayer solves various algorithm phase testing entirely with a drop-in replacement feature of the algorithm. The other adaptive algorithm is the optimizer plugger; it creates its own hyperparameters via evolutionary properties. The initialized parameters for each hyperparameter create a population, and the optimizer plugger chooses the best fit through steps. Then the population updates itself according to the fitness function i.e. loss function of the training. The optimizer plugger has also a drop-in replacement feature, and it has been demonstrated via testing different optimization algorithms. The main purpose of the optimizer plugger is not to outperform the existing algorithms, its purpose is to reduce the hyperparameter sensitivity of the attached optimization algorithm while maintaining the performance of the attached algorithm. The experiments and benchmarks of the proposed algorithms demonstrate how researchers can use the suggested methods. These experiments and benchmarks prove that deep learning can benefit from adaptive and drop-in solutions.

Keywords: Deep Learning, Optimization, Noise

Acknowledgements

Some calculations were performed on the TUBITAK TRUBA HPC Server. Sina thanks Mehmet SEKER and Betul Sefika ERTUGRUL for funding the research.

✉ Corresponding Author Email: *m.s.ertugrul@gmail.com*

Physics-Informed Feature Engineering for Photovoltaic Power Forecasting Using Inverter Telemetry

Özge Çelik[1]✉, Kadriye Filiz Balbal[2], Sebahattin İkikardeş[3]

[1] *Gördes İbn-i Sina Vocational and Technical Anatolian High School, Manisa, Türkiye*
[2] *Dokuz Eylül University, Faculty of Science, Computer Science Department, Izmir, Türkiye*
[3] *Balıkesir University, Institute of Science, Department of Mathematics, Balıkesir, Türkiye*

Abstract

Accurate photovoltaic (PV) power forecasting is essential for reliable grid operation and renewable energy integration. Physics-informed feature engineering can improve the representation of PV operating states in data-driven forecasting [1,2]. However, most forecasting studies emphasize historical power and meteorological variables, while compact physical descriptors derived directly from inverter-level electrical telemetry remain comparatively underexplored.

This study proposes a physics-informed feature engineering framework for short-term PV power forecasting using 30-min operational measurements from a 100-kW grid-connected inverter collected between December 2025 and August 2026. Available telemetry includes active and reactive power, total DC input power, three-phase AC currents, and individual PV-string currents. Missing observations are classified using daily production windows to distinguish physically inactive periods from genuine telemetry gaps, and permanently inactive strings are excluded. The remaining raw measurements are transformed into interpretable descriptors representing DC-side string behavior, inverter conversion efficiency, AC-side phase balance, reactive-power behavior, and short-term operating dynamics.

Pairwise correlation and variance inflation factor analysis are used to remove redundant descriptors, yielding nine physics-informed features. Ratio-based indicators are constrained under near-zero operating conditions to avoid numerical instability, while dynamic features use only present and past observations to prevent future-information leakage. The forecasting experiment compares a baseline using historical PV active power with an augmented configuration combining the same power history with the inverter-derived descriptors. Identical chronological partitions, forecasting horizon, model architecture, and training settings are used to isolate the contribution of inverter operational information.

The framework complements recent physics-informed and SCADA-based PV forecasting approaches [1,2] by focusing on physically interpretable information extracted from inverter telemetry rather than additional meteorological inputs. It provides a systematic basis for evaluating whether internal inverter operating states can improve short-term PV power forecasting.

Keywords: Photovoltaic power forecasting, inverter telemetry, physics-informed feature engineering, time-series forecasting, smart grids.

References

[1] Pombo, D. V., Bacher, P., Ziras, C., Bindner, H. W., Spataru, S. V., & Sørensen, P. E. (2022). Benchmarking physics-informed machine learning-based short term PV-power forecasting tools. Energy Reports, 8, 6512–6520.

[2] Uzel, H. (2026). SCADA-Based AC Power Forecasting in a Utility-Scale PV Plant: Explainable Hist Gradient Boosting and Thermal Derating Quantification. Gazi University Journal of Science Part A: Engineering and Innovation, 13(1), 452–482.

✉ Corresponding Author Email: *ozgephdcelik@gmail.com*

Forecast Horizon Matters: Explicit Temporal Memory Design for Multi-Horizon HVAC Load Forecasting

Seda Ermis

Osmaniye Korkut Ata University, Electrical - Electronics Engineering Department, Osmaniye, Türkiye

Abstract

Short-term HVAC load forecasting plays an important role in intelligent building energy management; however, the relationship between prediction horizon and required temporal memory remains insufficiently understood [1,2]. While many studies emphasize model architecture improvements, comparatively less attention has been paid to determining how much historical information is actually necessary for reliable forecasting at different prediction horizons [3,4]. This study investigates the impact of explicit temporal memory design on multi-horizon HVAC load forecasting using the PLEIAData Building A dataset at hourly resolution [5]. Forecast horizons of 1, 3, 6, 12, and 24 hours ahead are examined under a systematic feature engineering framework based on environmental variables, autoregressive load information, lagged historical observations, and rolling statistics.

A configuration-driven experimental pipeline is developed to compare multiple explicit memory strategies, ranging from core environmental features only to progressively richer lag- and rolling-based representations. Three machine learning architectures, namely XGBoost, LSTM, and GRU, are evaluated under identical experimental settings. Preliminary findings indicate that prediction performance appears to be more strongly influenced by temporal feature representation than by model architecture alone. The inclusion of current load, lagged historical observations, and rolling statistics substantially improves forecasting accuracy compared with non-temporal baseline configurations. Furthermore, the optimal memory configuration varies with forecasting horizon, suggesting that temporal memory configurations may depend on forecasting horizon rather than being universally fixed.

The preliminary findings suggest that forecasting horizon should be explicitly considered when designing temporal memory structures for HVAC load prediction, providing practical insights for intelligent building energy management.

Keywords: HVAC load forecasting, temporal memory, feature engineering, multi-horizon forecasting, intelligent buildings.

References

[1] Amasyali, K., & El-Gohary, N. M. (2018). A review of data-driven building energy consumption prediction studies. Renewable and Sustainable Energy Reviews, 81, 1192-1205.

[2] Liu, H., Liang, J., Liu, Y., & Wu, H. (2023). A review of data-driven building energy prediction. Buildings, 13(2), 532.

[3] Shafiuzzaman, M., Islam, M. S., Bashar, T. R., Munem, M., Nahiduzzaman, M., Ahsan, M., & Haider, J. (2025). Enhanced very short-term load forecasting with multi-lag feature engineering and prophet-XGBoost-CatBoost architecture. Energy, 137981.

[4] Li, Y., Arellano-Espitia, F., Aler, R., Igualada, L., & Corchero, C. (2025). Data-driven methods and their applications to building HVAC energy consumption prediction: A review. Journal of Building Engineering, 114612.

[5] Ibarra, A. M., González-Vidal, A., & Skarmeta, A. (2023). PLEIAData: consumption, HVAC, temperature, weather and motion sensor data for smart buildings applications. Scientific Data, 10(1), 118.

✉ Corresponding Author Email: *sedaermis@osmaniye.edu.tr*

Effect of Viscous Dissipation on Pulsating Flow and Heat Transfer for Non-Newtonian Fluid in a Pipe

Ayse Nur Altunkaya✉

Recep Tayyip Erdogan University, Department of Mechanical Engineering, Rize, Türkiye

Abstract

Heat transfer phenomena play a critical role in many engineering applications such as biomedical devices, electronic cooling, energy systems, and heat exchangers. In particular, pulsating flow, by periodically disturbing the hydrodynamic and thermal boundary layers, leads to significant changes in the flow and thermal characteristics. In addition, the use of non-Newtonian fluids in thermal systems has attracted considerable attention due to their complex rheological behavior and potential advantages in controlling flow and heat transfer characteristics. In this context, the interaction between pulsation parameters and non-Newtonian fluid characteristics can significantly influence the flow structure and heat transfer mechanisms. Therefore, a comprehensive understanding of the coupled effects of pulsation dynamics, fluid rheology, and viscous dissipation on heat transfer behavior is of considerable importance for the design of thermal systems.

In this study, an analytical investigation of pulsating flow and heat transfer of non-Newtonian fluid in a pipe with uniform heat flux at the wall, including viscous dissipation effect, is presented. It is assumed that the flow is fully developed both hydrodynamically and thermally. The period-averaged Nusselt number and temperature profiles are obtained for pseudoplastic, Newtonian, and dilatant fluids under different values of nondimensional frequency, amplitude, and Brinkman number by considering the power-law model and a series expansion approach based on the perturbation method. The results indicate that the dimensionless frequency, the Brinkman number, the amplitude and the power-law index are interactively effective on heat transfer. As the Brinkman number increases, the averaged Nusselt number decreases for all fluid types, and the maximum value of the Nusselt number shifts toward the lower frequency values. Furthermore, the Nusselt number exhibits pronounced discontinuities at specific values of the Brinkman numbers for all considered fluids.

Keywords: Pulsating flow, viscous dissipation, power-law fluid, perturbation method, heat transfer

✉ Corresponding Author Email: *aysenur.altunkaya@erdogan.edu.tr*

A Neural-Network-Based Framework for Cryptographic Systems under Hawkes-Driven Attacks

Derya Altıntan ✉

Hacettepe University, Mathematics Department, Ankara, Türkiye

Abstract

Cryptographic systems can be exposed to adversarial attacks whose complex dynamics can change over time. In general, these attacks occur at irregular times and involve randomness. These attack patterns affect the dynamics and performance of the cryptographic system of interest, leading to difficulties in understanding and predicting the system's behavior. In this work, we propose a neural-network-based framework for understanding the dynamics of cryptographic systems under stochastic attack conditions. We model attack events using a Hawkes process [1], while the system behavior is described by a Hawkes-driven ordinary differential equation (ODE) model [2]. A neural network (NN) model [3] is presented to learn the connection between attack parameters and the behavior of the Hawkes-driven ODE model. It is also utilized to reduce the computational cost of repeated simulations.

The overall approach combines stochastic modeling and machine learning in a single structure. Numerical results are presented to study approximation performance, computational efficiency of the NN, and to predict the behavior of the cryptographic system under unseen attack scenarios. The proposed approach provides a flexible framework for studying cryptographic systems under dynamic attack conditions and has the potential to be extended to more general settings in future work.

Keywords: Hawkes process, cryptographic systems, neural networks, stochastic models, adversarial attacks

References

[1] Hawkes, A. G. (1971). Spectra of some self-exciting and mutually exciting point processes. Biometrika, 58(1), 83-90.
[2] Nwokoye, C. H. (2026). A Survey of SIR-Based Differential Epidemic Models for Control and Security Against Malware Propagation in Computer Networks. Security and Privacy, 9(1), e70138.
[3] Schmidhuber, J. (2015). Deep learning in neural networks: An overview. Neural networks, 61, 85-117.

✉ Corresponding Author Email: *deryaaltintan@hacettepe.edu.tr*

Diffusion bridge with random terminal time arising in fish population dynamics

Hidekazu Yoshioka ✉

Japan Advanced Institute of Science and Technology, Graduate School of Advanced Science and Technology, Nomi, Japan

Abstract

Understanding the population dynamics of migratory fish is a crucial issue related to the environment and biological resources. Various studies have conducted multifaceted analyses of the migration patterns of the fish *Plecoglossus altivelis altivelis* (Ayu), a major fishery resource in Japan that is deeply intertwined with regional socio-cultural aspects. While quantifying the number of juveniles migrating upstream in spring from seas to rivers has been considered important for understanding the population dynamics of Ayu, their theoretical studies have been quite limited, except for the recent studies based on the stochastic differential equations (SDEs) with pinned initial and terminal conditions [1,2]. A limitation of these studies is that they constructed models based solely on data on the number of migrants. In this study, we extend the previous SDEs by incorporating environmental factors, particularly water temperature, as an influential factor. This extension leads to a novel diffusion bridge with random terminal time whose well-posedness being non-trivial. We present a sufficient condition for well-posing the proposed model and present some computational results.

Keywords: Fish migration, Diffusion bridge with randon terminal time, Well-posedness; Sample path generation

Acknowledgements

We would like to express his gratitude to the Japan Water Agency, Ibi River, and Nagara River General Management Office for providing valuable fish migration data of *Plecoglossus altivelis altivelis* observed at the Nagara River Estuary Barrage. This study was supported by the Japan Science and Technology Agency (PRESTO No. JPMJPR24KE).

References

[1] Yoshioka, H. (2025). CIR bridge for modeling of fish migration on sub-hourly scale, Chaos, Solitons & Fractals, 199(Part 2), 116874. https://doi.org/10.1016/j.chaos.2025.116874

[2] Yoshioka, H. (2026). A minimization principle behind the diffusion bridge of diurnal fish migration. Mathematical Biosciences, 396, 109684. https://doi.org/10.1016/j.mbs.2026.109684

✉ Corresponding Author Email: *yoshih@jaist.ac.jp*

A Physics-Informed Neural Network Framework for the Brusselator Reaction–Diffusion System with Cross-Diffusion

Gülden Mülayim✉

Adıyaman University, Mathematics Department, Adıyaman, Türkiye

Abstract

Linear reaction–diffusion system with cross-diffusion arising from the mathematical modeling of pattern formation in biology and chemical kinetics are typically characterized by stiff coupling between diffusion, cross-diffusion and reaction terms, which renders their numerical treatment computationally demanding for classical mesh-based schemes such as finite difference, finite element, and Galerkin-type methods. The Brusselator model is a benchmark problem for assessing the robustness of numerical solvers, particularly when cross-diffusion terms are incorporated and Turing-type instabilities give rise to spatially heterogeneous patterns. The recent emergence of physics-informed neural networks (PINNs), in which the residuals of the governing partial differential equations together with the initial and boundary conditions are embedded directly into the loss function via automatic differentiation, has provided a mesh-free alternative for both forward and inverse problems. In this study, a PINN framework is developed for two-dimensional Brusselator reaction–diffusion system with cross-diffusion. A fully connected feed-forward network with hyperbolic tangent activation functions is trained using a composite loss that linearly combines the PDE residual, initial, and boundary terms; the Adam optimizer is employed for initial training, which is subsequently refined by an L-BFGS quasi-Newton update. The accuracy of the proposed scheme is quantified using relative L^2 error norms with respect to reference solutions obtained from high-resolution finite-difference computations, and the influence of network depth, width, collocation-point distribution, and loss-term weighting on convergence behavior is systematically examined. Numerical experiments demonstrate that the PINN solver reproduces the stiff dynamics and Turing patterns of the Brusselator system with high fidelity, offering a flexible, mesh-free methodology.

Keywords: Brusselator model, Reaction–diffusion systems, Cross-diffusion, Physics-informed neural networks, Turing patterns.

References

[1] Raissi, M., Perdikaris, P., & Karniadakis, G. E. (2019). Physics-informed neural networks: A deep learning framework for solving forward and inverse problems involving nonlinear partial differential equations. Journal of Computational Physics, 378, 686–707.

[2] Hariri, I., Radid, A., & Rhofir, K. (2025). Physics-informed neural networks methodology for the resolution of some Turing's type models. Advanced Mathematical Models & Applications, 10(1), 61–80.

[3] Dehghan, M., & Abbaszadeh, M. (2016). Variational multiscale element free Galerkin (VMEFG) and local discontinuous Galerkin (LDG) methods for solving two-dimensional Brusselator reaction–diffusion system with and without cross-diffusion. Computer Methods in Applied Mechanics and Engineering, 300, 770–797.

[4] Hariri, I., Radid, A., & Rhofir, K. (2024). Physics-informed neural networks for the reaction–diffusion Brusselator model. Mathematical Modeling and Computing, 11(2), 448–457.

[5] Lagaris, I. E., Likas, A., & Fotiadis, D. I. (1998). Artificial neural networks for solving ordinary and partial differential equations. IEEE Transactions on Neural Networks, 9(5), 987–1000.

✉ Corresponding Author Email: gmulayim@adiyaman.edu.tr

Attention U-Net for SAR Backscatter Prediction from Sentinel-2 Imagery in the Aralkum Desert: An Optical-to-SAR Translation Framework

Rashid Nasimov[1]✉, Nigorakhon Nasimova[2], Charos Khidirova[2], Akmalbek Abdusalomov[3], Young-Im Cho[3]

[1] *Tashkent State University of Economics, Artificial Intellegence Department, Tashkent, Uzbekistan*
[2] *Tashkent University of Information Technologies, Computer Systems Department, Tashkent, Uzbekistan*
[3] *Department of Computer Engineering, Gachon University Gyeonggi-Do, Republic of Korea*

Abstract

Optical remote sensing offers a convenient and affordable way to monitor large areas, but cloud cover and atmospheric dust frequently interrupt data acquisition. Synthetic Aperture Radar (SAR) overcomes this limitation by penetrating clouds, making SAR-to-optical translation an important research area.

This study presents a deep learning framework for predicting Sentinel-2 multispectral imagery from SAR backscatter in the Aralkum Desert, Central Asia is a region dominated by salt crusts and sparse, dry vegetation. An Attention U-Net model was trained on paired BIOMASS L1 SAR data with four polarisations (HH, HV, VH, VV) and 11 Sentinel-2 spectral bands, co-registered at 30-metre resolution. A total of 2,313 paired tiles of 128×128 pixels were extracted through a rigorous pipeline that included quality control and percentile clipping with z-score standardisation, specifically adapted for the skewed reflectance distributions typical of salt-affected arid terrain.

The Attention U-Net uses spatial attention gates to suppress irrelevant background responses and amplify meaningful signals. Each gate combines decoder gating signals with encoder skip connection features, producing soft spatial weight maps. The network includes four encoder blocks, a bottleneck, and four decoder blocks with matching attention gates. A linear output layer allows unbounded predictions consistent with standardised target values. GAN-based training was explored but abandoned due to mode collapse. An L1 pre-training strategy also proved unstable. The final model was trained exclusively with L1 loss, prioritising pixel-level accuracy over perceptual sharpness is a more appropriate objective for quantitative satellite image prediction.

The model achieves a test set Mean Absolute Error of 0.1039 on normalised data, representing competitive performance for single-date SAR-to-optical translation.

Keywords: Synthetic Aperture Radar (SAR), Optical remote sensing data, Attention U-Net

Acknowledgements

The authors thank the European Space Agency (ESA) for providing BIOMASS L1 SAR and Sentinel-2 data for the tools used in this research.

References

[1] Liu, Y., Han, Q., Yang, H., & Hu, H. (2024). High-Resolution SAR-to-Multispectral Image Translation Based on S2MS-GAN. *Remote Sensing*, *16*(21), 4045. https://doi.org/10.3390/rs16214045

[2] Schultz, M.; Clevers, J.G.P.W.; Carter, S.; Verbesselt, J.; Avitabile, V.; Quang, H.V.; Herold, M. Land Cover Change Detection in the Aralkum with Multi-Source Satellite Datasets. GIScience Remote Sens. 2022, 59, 135–151. https://doi.org/10.1080/15481603.2021.2009232

✉ Corresponding Author Email: *rashid.nasimov@tsue.uz*

Numerical computation of Fisher-Rao gradient flow to understand the biological structure of radiolarians

Keiko Arase ✉, Hidekazu Yoshioka

Japan Advanced Institute of Science and Technology, Graduate School of Advanced Science and Technology, Nomi, Japan

Abstract

This study presents a simple algorithm for minimizing interacting free energy [1] based on Fisher-Rao gradient flow and attempts to describe the process of material density rearrangement under spherical symmetry as the time evolution of a probability density function. While Fisher-Rao gradient flow has mainly been applied in statistical machine learning, we are conducting fundamental research toward its application to the skeletal formation of radiolarians, which have near-spherical biological structures. Ying [1] proposed updating the discrete probability distribution based on logarithmic representation, but this study does not use such a redundant method and directly solves the governing equation of the probability density function. To achieve this, we directly introduce appropriate correction terms to satisfy the mass conservation condition into the governing equations and perform discrete discretization while preserving a certain symmetry at the discrete level. By modulating each term in the corresponding energy of the gradient flow, we numerically investigate how the concentration and diffusion of the probability density and the changes in the radial distribution occur and explore the possibility of extending this to a layered structure.

Keywords: Fisher-Rao gradient flow, radiolarian, Minimizing Interacting Free Energy

Acknowledgements

This study was supported by the Japan Society for the Promotion of Science (KAKENHI No. 25K00240).

References

[1] Ying, L. (2020). Mirror Descent Algorithms for Minimizing Interacting Free Energy. Journal of Scientific Computing, 84(3), 51. https://doi.org/10.1007/s10915-020-01303-z.

✉ Corresponding Author Email: *s2640010@jaist.ac.jp*

On the BEM and the MFS solutions of diffusion equations in coupled domains

Pelin Şenel ✉

Karadeniz Technical University, Mathematics Department, Trabzon, Türkiye

Abstract

In this study, the two numerical methods, namely the boundary elements method (BEM) and the method of fundamental solutions (MFS), are compared on the numerical solution of the steady-state diffusion equations in coupled domains. The problem is considered on a square domain that is a composed of two non-overlapping regions separated by a curved interface. The continuation of the potential and the flux conditions is applied on the interface boundary. In the numerical implementations the fundamental solution of the Laplace equation is employed [1]. The BEM-discretized matrix-vector equations are constructed by using the constant elements. The resultant linear equations for the two subdomains are coupled and solved in one stroke by imposing the external boundary conditions and the interface continuity conditions [2]. In the MFS, the two subdomains are treated separately and combined by the coupled interface conditions [3,4]. It is observed that both methods give accurate and convergent results. In terms of the computer implementation, MFS is easier than the BEM, but the placement of the source points plays a critical role on the stability of the solutions in MFS.

Keywords: BEM, MFS, coupled domains

Acknowledgements

The initial guidance of Prof. Daniel Lesnic on the construction of the MFS solution is acknowledged.

References

[1] Pozrikidis, C. (1992) Boundary Integral and Singularity Methods for Linearized Viscous Flow. Cambridge University Press, Cambridge.

[2] Senel, P., & Tezer-Sezgin, M. (2019). DRBEM solution to MHD flow in ducts with thin slipping side walls and separated by conducting thick Hartmann walls, Computers & Mathematics with Applications, 78(9), 3165-3174.

[3] Berger, J.R., & Karageorghis, A. (1999). The method of fundamental solutions for heat conduction in layered materials. International Journal for Numerical Methods in Engineering, 45, 1681-1694.

[4] Dyhoum, T.E., Lesnic, D., & Aykyord R.G. (2014). Solving the complete electrode direct model of ERT using the boundary element method and the method of fundamental solutions. Electronic Journal of Boundary Elements, 12(3), 26-71.

✉ Corresponding Author Email: *psenel@ktu.edu.tr*

Hyper-Heuristic Solution Approaches for the Dual Resource Constrained Flexible Job Shop Scheduling Problem with Heterogenous Worker Flexibility

Pınar Yunusoğlu[1,2]✉, Fehmi Burçin Özsoydan[3]

[1] *Dokuz Eylül University, The Graduate School of Natural and Applied Sciences, İzmir, Türkiye*
[2] *İzmir Bakırçay University, Industrial Engineering Department, İzmir, Türkiye*
[3] *Dokuz Eylül University, Industrial Engineering Department, İzmir, Türkiye*

Abstract

The dual resource constrained manufacturing system constrained by machine and human resources was first introduced in [1]. The earlier studies on dual resource constrained scheduling problems primarily focused on homogeneous workers, in which the workers have the same operational efficiency. They implicitly assumed the standard processing times for the operations, regardless of the worker allocations. However, the efficiency of the workers may vary depending on operational skills and proficiency. This is referred to as heterogeneous worker flexibility. This study addresses the dual resource constrained flexible job shop scheduling problem with heterogeneous worker flexibility. The dual resource constrained flexible job shop scheduling problem is challenging to solve since it requires allocation of both machines and workers [2]. Therefore, Q-learning based hyper-heuristic solution approaches are developed to solve the problem. The proposed Q-learning based hyper-heuristic solution approaches employ various state evaluation functions and Q-learning based heuristic generation/selection mechanisms to enhance the performance of the hyper-heuristics. The performance of the proposed heuristic selection mechanisms is compared with the heuristic selection functions available in the literature. The flexible job shop scheduling benchmark problems are extended to the dual resource constrained flexible job shop scheduling problem to compare the performance of the proposed solution approach with the adaptive large neighborhood search. The proposed solution approach outperforms the adaptive large neighborhood search in terms of solution quality and computation time. The results indicate that the Q-learning algorithm monitors the current search status of the algorithm by using effective state evaluation functions and significantly improves the performance of the hyper-heuristic.

Keywords: Dual resource, flexible job shop scheduling, hyper-heuristic

Acknowledgements

This work is supported by The Scientific and Technological Research Council of Türkiye (TÜBİTAK) under Grant No. 126M038.

References

[1] Nelson, R.T. (1967). Labor and Machine Limited Production Systems. Management Science, 13(9), 648–671.

[2] Lobo, B.J., Hodgson, T.J., King, R.E., Thoney, K.A., & Wilson, J.R. (2013). Allocating job-shop manpower to minimize Lmax: Optimality criteria, search heuristics, and probabilistic quality metrics. Computers & Operations Research, 40(10), 2569–2584.

✉ Corresponding Author Email: *pinar.yunusoglu@bakircay.edu.tr*

A Fuzzy Logic-Based Musical Cryptography Model for Text-to-Note Transformation

Melike Kaysal ✉

Tofaş Science High School, Bursa, Turkey

Abstract

In this study, an original musical encryption model was developed by integrating mathematical frequency analysis, musical notes, modular arithmetic, and a fuzzy-logic-based decision mechanism. The aim is to propose an artificial intelligence-supported approach that converts texts into audible note sequences and decodes these sequences back into text. Initial trials showed that some lower-octave sounds were not sufficiently audible in the digital environment [1]. Therefore, 72 notes in the 3rd to 8th octave range were used. These frequencies were then subjected to the Mod 29 operation to associate them with the 29 letters of the Turkish alphabet. The resulting remainder values were sorted in ascending order, and the natural frequency order was reorganized accordingly, reducing predictable note-to-letter patterns.

Since a one-letter–one-note mapping was considered weak against frequency analysis, a homophonic encryption approach was adopted. Turkish letter usage frequencies and the Krumhansl–Kessler major key profiles were used as inputs to the fuzzy logic system [2]. Letter frequencies and pitch-class weights were evaluated through low, medium, and high membership functions, while the number of notes assigned to each letter was determined at few, medium, and many levels [3]. Thus, frequently used letters were assigned more notes, while rarely used letters were assigned fewer. This increased encryption diversity and produced a more balanced melodic output [4,5]. The resulting note–letter table was implemented in MATLAB, where an interface was developed to encode text into notes, decode notes back into text, and play the generated melody. As a result, the study presents an original interdisciplinary approach to musical cryptology by combining mathematical modelling, musical representation, and an artificial intelligence-supported decision mechanism.

Keywords: Musical cryptology, fuzzy logic, note–letter transformation, MATLAB

References

[1] Karadağ, Ö. (2020). Türkçe eğitimi açısından ses-harf sıklığı üzerine bir değerlendirme. Ana Dili Eğitimi Dergisi, 8(1), 1-13.
[2] Krumhansl, C. L., & Kessler, E. J. (1982). Tracing the dynamic changes in perceived tonal organization in a spatial representation of musical keys. Psychological review, 89(4), 334.
[3] Zadeh, L. A. (1965). Fuzzy sets. Information and control, 8(3), 338-353.
[4] Hilger, A. I., Cole, J., & Larson, C. (2023). Semantic focus mediates pitch auditory feedback control in phrasal prosody. Language, cognition and neuroscience, 38(3), 328-345.
[5] Yılmaz, M., & Ballı, S. (2016). Veri Şifreleme Algoritmalarının Kullanımı İçin Akıllı Bir Seçim Sistemi Geliştirilmesi. Uluslararası Bilgi Güvenliği Mühendisliği Dergisi, 2(2), 18-28.

✉ Corresponding Author Email: *kaysalmelike@gmail.com*

Prony series representability of some fractional viscoelastic materials

Dimiter Prodanov✉

IICT, PAML-LN, Sofia, Bulgaria

Abstract

Linear viscoelastic materials are ubiquitous in engineering applications—from polymers and biological tissues to damping systems. While their fundamental description uses continuous relaxation spectra, practical finite element simulations and system identification routines rely on finite Prony series [1,2]. This work provides a rigorous Mellin-domain framework to bridge this gap. We establish an arithmetic criterion that determines exactly when a material admits a finite Prony series (classical spring-dashpot networks) versus when it requires an infinite ladder (fractional models). For the canonical case of Mittag-Leffler relaxation [1] that models power-law behavior in polymers, soft tissues, and rubber-like materials we construct an infinite Prony series with geometrically spaced relaxation times and explicit positive weights. We prove weak convergence of the discrete ladder to the continuous spectrum and derive an exponential error bound, ensuring that truncation to a modest number of terms yields machine-precision accuracy. The results enable direct implementation of fractional viscoelastic models into existing Prony-series-based simulation environments without modifying solver cores. This creates new opportunities for data-driven material characterization, reduced-order modelling, and real-time control of viscoelastic systems in manufacturing, energy, and biomechanics.

Keywords: Fractional viscoelasticity · Prony series · Mittag-Leffler function · Relaxation spectrum · Finite element modelling · Material characterization

Acknowledgements

The present work was funded by the European Union's Horizon Europe program under grant agreement VIBraTE 101086815.

References

[1] Mainardi, F. (2010). Fractional Calculus and Waves in Linear Viscoelasticity. Imperial College Press, London.

[2] Hristov, J. (2022) Prony's series and modern fractional calculus, in Multi-Chaos, Fractal and Multi-Fractional Artificial Intelligence of Different Complex Systems, Academic press, 187 - 200

✉ Corresponding Author Email: *dimiter.prodanov@iict.bas.bg*

A Mathematical Model of Glymphatic Dysfunction and Neuroinflammation in Multiple Sclerosis

Sümran Gücü and Necati Özdemir

Balıkesir University, Department of Mathematics, Balıkesir, Türkiye

Abstract

Multiple sclerosis is a chronic neuroinflammatory disease characterized by immune-mediated demyelination and progressive neurodegeneration within the central nervous system. Although the exact mechanisms driving disease progression remain incompletely understood, increasing evidence suggests that dysfunction of the glymphatic system may contribute to the accumulation of inflammatory mediators and myelin debris, thereby exacerbating neuroinflammation and tissue damage. Understanding the interaction between glymphatic clearance and inflammatory processes is therefore important for investigating MS progression and identifying potential therapeutic targets. In this study, a nonlinear mathematical model is proposed to describe the dynamics of myelin damage, neuroinflammation, activated microglia, and glymphatic clearance. The model consists of a system of four coupled ordinary differential equations representing the major biological interactions involved in disease progression. Fundamental mathematical properties of the model, including positivity, boundedness, existence of equilibrium points, and local stability conditions, are established. Furthermore, a threshold parameter analogous to the basic reproduction number is derived to characterize or pathological activity within the system. The analytical results indicate that impaired glymphatic function promotes the accumulation of inflammatory factors and increases microglial activation, leading to enhanced demyelination. Conversely, improved glymphatic clearance reduces neuroinflammation and contributes to the stabilization of myelin integrity. These findings support the hypothesis that the glymphatic system plays a protective role in MS and demonstrate how mathematical modeling can provide insight into complex neuroimmune interactions. The proposed framework may serve as a basis for future numerical investigations and the evaluation of therapeutic strategies targeting glymphatic function in neurodegenerative diseases.

Keywords: Multiple sclerosis, Glymphatic clearance, Nonlinear dynamical systems, Neuroinflammation, Microglial activation, Equilibrium analysis, Stability theory

Acknowledgements

This study was financially supported by Balıkesir University Scientific Research Projects Unit under Grant No. BAP 2024/73. I would like to express my gratitude to my esteemed professors Doctor Eren Altun, for their invaluable contributions to the development and interpretation of my model.

References

[1] Reich, D. S., Lucchinetti, C. F., & Calabresi, P. A, (2018), *Multiple sclerosis.*New England Journal of Medicine, 378(2), 169–180.
[2] Dendrou, C. A., Fugger, L., & Friese, M. A. (2015), *Immunopathology of multiple sclerosis.*Nature Reviews Immunology, 15(9), 545–558.
[3] Rasmussen, M. K., Mestre, H., & Nedergaard, M. (2018), *The glymphatic pathway in neurological disorders.* The Lancet Neurology, 17(11), 1016–1024.
[4] Carotenuto, A., Giordano, B., Dervenoulas, G., et al. (2022), *Glymphatic system impairment in multiple sclerosis.* Frontiers in Neurology, 13, 81732

Corresponding Author Email: *sumran.gc@gmail.com*, *nozdemir@balikesir.edu.tr*

Operational Research Applications in Agriculture: Trends, Methods, and AI Integration

Semiha Erkovan ✉, Deniz Türsel Eliiyi

İzmir Bakircay University, Industrial Engineering Department, İzmir, Turkey

Abstract

The agricultural sector has become an increasingly important field for the application of Operational Research (OR), optimization, and mathematical modelling techniques as productivity, efficient resource utilization, sustainability, and informed decision-making have gained greater importance [1,2]. However, existing studies generally focus on specific methods, technologies, or agricultural sub-fields, while comprehensive reviews examining how OR-based approaches are integrated with modern techniques and artificial intelligence applications remain limited. This study aims to provide a holistic review of the OR literature in agriculture, with particular emphasis on modern technique and AI integration in OR-based agricultural studies. The Web of Science Core Collection database was used, and a multi-stage screening and selection process was followed. Studies that passed the quality assessment were subjected to content-based analysis. The analysis examined publication and citation trends, major application themes, commonly used OR methods, decision levels, modern techniques or AI components employed, data sets used, and the main outcomes obtained from these integrations.

The findings show that literature has grown significantly over time and has gained increasing impact in recent years. Studies are mainly concentrated in agri-food supply chains and logistics, followed by production and farm-level planning and smart farming. Methodologically, mathematical programming, metaheuristic and hybrid methods, multi-criteria decision-making approaches, and review/conceptual studies stand out. The analysis further reveals that studies mostly focus on the strategic decision-making level, while operational and tactical problems remain relatively underexplored. Overall, this study clarifies the current structure of OR-based agricultural research and provides a guiding framework for future studies integrating OR, AI, data-driven technologies, and sustainable agricultural decision-making.

Keywords: Agricultural Systems, Operations Research, AI integration, Modern Technics

Acknowledgements

This study was supported under Project No. TEZ.2026.006, funded by the Scientific Research Projects Coordination Office at Izmir Bakırçay University.

References

[1] Borodin, V., Bourtembourg, J., Hnaien, F., & Labadie, N. (2016). Handling uncertainty in agricultural supply chain management: A state of the art. *European Journal of Operational Research*, *254*(2), 348-359.

[2] Ahumada, O., & Villalobos, J. R. (2009). Application of planning models in the agri-food supply chain: A review. *European journal of Operational research*, *196*(1), 1-20.

✉ Corresponding Author Email: *semiha.kusbeci@bakircay.edu.tr*

Explainable Climate Intelligence Through Temporal Feature Engineering

Safaa Kahil[1,2]✉, Omar Jellouli[2], Mohamed Fihri[1]

[1] *Laboratory of Mathematics, Statistics and Applications, Faculty of Sciences, Mohammed V University in Rabat, Rabat, 1014, Morocco*
[2] *International University of Rabat, College of Engineering and Architecture, TICLab, 11100, Sala Al Jadida, Morocco*

Abstract

Accurate climate forecasting is essential for environmental monitoring, renewable energy management, and sustainable engineering applications. While recent studies have focused on developing increasingly complex machine learning models, the impact of temporal feature engineering remains insufficiently explored. This study investigates how engineered temporal features can improve both the accuracy and interpretability of climate forecasting models. A comprehensive set of temporal descriptors, including lag variables, rolling statistics, and cyclical time representations, was extracted from historical meteorological data. These features were integrated into four forecasting models: LightGBM, Random Forest, Long Short-Term Memory (LSTM), and Gated Recurrent Unit (GRU). Bayesian Optimization was employed to identify optimal hyperparameter settings, while SHAP analysis was used to explain model predictions and quantify feature importance. The results show that temporal feature engineering significantly enhances forecasting performance across all models. Compared with models trained on raw data, prediction errors were reduced by 29.9% for LightGBM, 28.2% for Random Forest, 15.6% for LSTM, and 16.6% for GRU. The best performance was achieved by the optimized LightGBM model, with an RMSE of 0.9842, MAE of 0.7106, and R^2 of 0.9666. Statistical tests confirmed the significance of these improvements. SHAP analysis further revealed that lagged temperature values and rolling statistics were the most influential predictors. These findings demonstrate that temporal feature engineering provides an effective and interpretable framework for improving climate forecasting performance while maintaining model transparency.

Keywords: Temporal feature engineering, Short-term temperature forecasting, Climate intelligence

References

[1] S. Hochreiter and J. Schmidhuber, "Long short-term memory," *Neural Computation*, vol. 9, no. 8, pp. 1735–1780, 1997.
[2] K. Cho, B. Van Merriënboer, C. Gulcehre, D. Bahdanau, F. Bougares, H. Schwenk, and Y. Bengio, "Learning phrase representations using RNN encoder–decoder for statistical machine translation," *Proc. EMNLP*, pp. 1724–1734, 2014.
[3] L. Breiman, "Random forests," *Machine Learning*, vol. 45, no. 1, pp. 5–32, 2001.
[4] G. Ke, Q. Meng, T. Finley, et al., "LightGBM: A highly efficient gradient boosting decision tree," *Advances in Neural Information Processing Systems*, vol. 30, pp. 3146–3154, 2017.
[5] S. M. Lundberg and S. I. Lee, "A unified approach to interpreting model predictions," *Advances in Neural Information Processing Systems*, vol. 30, pp. 4765–4774, 2017.

✉ Corresponding Author Email: safaa.kahil@um5r.ac.ma

When Should We Translate? A Translation-Aware Probabilistic Routing Framework for Cost-Efficient Multilingual Text Classification

Wajdi Ben Saad[1]✉, Safa Madiouni [2]

[1] *Carthago Labs, Paris, France*
[2] *Paris Dauphine University, Paris, France*

Abstract

Multilingual text classification systems often rely either on direct inference with a multilingual encoder or on a translate-then-classify pipeline. These two strategies involve different trade-offs: direct multilingual inference avoids translation overhead, while translation can improve downstream classification when the target-language representation of the multilingual model is weak. However, translation also introduces latency, computational cost, and the risk of semantic distortion.

This paper proposes a translation-aware probabilistic routing framework for deciding when translation is worth using. For each input, the method estimates the expected reliability of the direct multilingual path and compares it with the expected reliability of the translation-based path. The translation path combines two factors: the estimated quality of the translation and the confidence of the English classifier after translation. Translation is selected only when this expected gain is large enough to justify its additional computational cost.

The proposed routing rule defines a simple decision boundary between direct classification and translate-then-classify. It is evaluated against direct-only classification, translation-only classification, and fixed language-based routing using Macro-F1, latency, translation rate, and estimated inference cost. The contribution is an interpretable cost-sensitive decision rule that avoids both systematic translation and blind trust in multilingual models.

Keywords: Multilingual classification; machine translation; probabilistic routing; cost-sensitive inference; efficient AI.

References

[1] Mikel Artetxe, Vedanuj Goswami, Shruti Bhosale, Angela Fan, and Luke Zettlemoyer. 2023. Revisiting Machine Translation for Cross-lingual Classification. In Proceedings of the 2023 Conference on Empirical Methods in Natural Language Processing, pages 6489–6499, Singapore. Association for Computational Linguistics.

[2] team, N., Costa-jussà, M.R., Cross, J., cCelebi, O., Elbayad, M., Heafield, K., Heffernan, K., Kalbassi, E., Lam, J., Licht, D., Maillard, J., Sun, A., Wang, S., Wenzek, G., Youngblood, A., Akula, B., Barrault, L., Gonzalez, G.M., Hansanti, P., Hoffman, J., Jarrett, S., Sadagopan, K., Rowe, D., Spruit, S.L., Tran, C., Andrews, P.Y., Ayan, N.F., Bhosale, S., Edunov, S., Fan, A., Gao, C., Goswami, V., Guzmán, F.(., Koehn, P., Mourachko, A., Ropers, C., Saleem, S., Schwenk, H., & Wang, J. (2022). No Language Left Behind: Scaling Human-Centered Machine Translation. ArXiv, abs/2207.04672.

[3] Guo, C., Pleiss, G., Sun, Y. & Weinberger, K.Q.. (2017). On Calibration of Modern Neural Networks. Proceedings of the 34th International Conference on Machine Learning, Proceedings of Machine Learning Research 70:1321-1330 Available from https://proceedings.mlr.press/v70/guo17a.html.

✉ Corresponding Author Email: *wajdi@carthagolabs.org*

Localized Magnetic Control of MHD Mixed Convection of Casson Fluid in a Lid-Driven Cavity: A DRBEM Approach

F. Sidre Oğlakkaya ✉

Osmaniye Korkut Ata University, Department of Mathematics, Osmaniye, Turkey

Abstract

This study investigates the magnetohydrodynamic (MHD) mixed convection heat transfer of a non-Newtonian Casson fluid within a lid-driven square cavity, utilizing the Dual Reciprocity Boundary Element Method (DRBEM). Fluid motion in the enclosure is driven by the sliding left wall combined with buoyancy forces arising from lateral thermal gradients [1]. Unlike conventional setups that apply a uniform magnetic field across the entire domain, this research introduces a spatially localized magnetic field restricted to specific subregions. This targeted approach generates localized Lorentz forces, allowing for the precise modulation of vortex dynamics, momentum transport, and thermal behavior without uniformly dampening the entire flow field [2]. The governing coupled equations for momentum and energy are formulated using a stream function–vorticity framework. By employing the dual reciprocity technique, highly nonlinear domain contributions—including convective transport, buoyancy, Casson fluid rheology, and the localized MHD source terms—are effectively transformed into equivalent boundary integrals. This boundary-only discretization scheme eliminates the requirement for extensive internal domain meshing. Consequently, the DRBEM framework yields significant computational efficiency, robust numerical stability, and highly accurate boundary resolution [3]. A detailed parametric analysis is conducted to systematically evaluate the impacts of magnetic field intensity, the spatial coordinates and size of the activation zone, and the distinct rheological properties of the Casson fluid. Ultimately, the simulations demonstrate that localized magnetic actuation serves as an exceptionally effective mechanism for selective vortex suppression and targeted thermal management. These insights provide foundational principles for the design and optimization of advanced thermal systems in materials processing, biomedical engineering, and magnetically controlled heat transfer applications.

Keywords: Casson fluid, Magneto-hydrodynamics (MHD), Dual Reciprocity Boundary Element Method (DRBEM), Partially active magnetic field, Lid-driven cavity.

References

[1] Ali, M. M., Akhter, R., & Alim, M. A. (2021). Performance of flow and heat transfer analysis of mixed convection in Casson fluid filled lid driven cavity including solid obstacle with magnetic impact. *SN Applied Sciences*, *3*(2), 250.

[2] Pekmen Geridonmez, B., & Oztop, H. F. (2021). Mixed convection heat transfer in a lid-driven cavity under the effect of a partial magnetic field. *Heat Transfer Engineering, 42*(10), 875–887.

[3] Partridge, P. W., Brebbia, C. A., & Wrobel, L. C. (1992). *The dual reciprocity boundary element method*. Computational Mechanics Publications.

✉ Corresponding Author Email: *fsidreoglakkaya@osmaniye.edu.tr*

A Customer Behavior-Informed Framework for Demand Forecasting and Inventory Optimization Using Machine Learning and Mixed-Integer Programming

Fatma Neşe Özen[1]✉, Ayhan Özgür Toy[1], Yücel Öztürkoğlu[2]

[1] *Yaşar University, Industrial Engineering Department, Izmir, Turkey*
[2] *Yaşar University, Logistics Management Department, Izmir, Turkey*

Abstract

Effective inventory management relies heavily on accurate demand forecasting and efficient decision-making under uncertainty [1]. However, demand variability is influenced not only by seasonal fluctuations, market conditions, and supply chain disruptions, but also by customer purchasing behavior [2]. Despite its importance, customer behavior is often overlooked in traditional forecasting approaches, which primarily rely on historical demand observations and may therefore fail to adequately capture the factors underlying demand fluctuations [3]. As a result, forecasting inaccuracies may lead to excessive inventory levels, stock shortages, increased operational costs, and reduced service performance.

To address this limitation, this study proposes a customer behavior-informed framework that integrates machine learning-based demand forecasting with MIP for inventory optimization. The proposed framework investigates whether incorporating customer behavior information can improve demand prediction accuracy and inventory decisions. In the forecasting stage, ARIMA is employed as a traditional statistical benchmark method based on historical demand data, while XGBoost incorporates both historical demand data and customer-related behavioral features reflecting purchasing patterns. Forecasting performance is evaluated using MAE, RMSE and MAPE.

The resulting demand forecasts are subsequently used as inputs to a MIP inventory model. The optimization model determines cost-efficient inventory decisions by minimizing ordering, holding, and shortage costs. By comparing inventory results obtained from different forecasting approaches, the study seeks to examine the extent to which customer behavior information contributes not only to forecasting performance but also to inventory performance. The proposed framework contributes to the intersection of operational research and artificial intelligence by providing an integrated approach for demand forecasting and inventory optimization.

Keywords: Inventory Management, Demand Forecasting, Customer Behavior

References

[1] Harahap, A.Z.M.K., Abdul Rahim, M.K.I., Malinjasari, N., Mat Salleh, S., & Ma'arof, R.A. (2025). Enhancing the Inventory Management through Demand Forecasting. International Journal of Research and Innovation in Social Science, 9(1), 2737–2744.

[2] Dulam, R., Furuta, K., & Kanno, T. (2021). Consumer Panic Buying: Realizing Its Consequences and Repercussions on the Supply Chain. Sustainability, 13(8), 4370.

[3] Kalchschmidt, M., Verganti, R., & Zotteri, G. (2006). Forecasting demand from heterogeneous customers. International Journal of Operations & Production Management, 26(5/6), 619–638.

✉ Corresponding Author Email: nese.ozen@yasar.edu.tr

A Preliminary Machine Learning Framework for Network Lifetime Estimation in Grid-Free Wireless Sensor Networks

Esra Çelik ✉

Atatürk University, Industrial Engineering Department, Erzurum, Türkiye

Abstract

Numerous sensors work together to form Wireless Sensor Networks (WSNs) to perform a specific task and monitor remote or hostile environments [1]. WSNs must be designed to maximize network lifetimes, taking into account constraints such as energy, coverage, and budget. To this end, decisions regarding the location of sensors and sinks, sensor activity schedules, and data flows must be considered integrally during the design phase [2]. Çelik and Keskin [3], discussing design problems for grid-free WSNs where sensors are positioned more flexibly, developed an optimization-based nonlinear mathematical model. Networks with this grid-free WSN design model had longer network lifetimes in small and medium-sized sensor network examples compared to grid-based distribution and random placement approaches. However, the high computation times of the grid-free model and its inability to provide solutions in reasonable timeframes for larger sensor network examples emerged as significant limitations. This study proposes a Random Forest-based machine learning framework to estimate network lifetimes for large-scale sensor network samples from optimal solutions obtained from a grid-free mixed integer programming model. The proposed approach provides a fast and data-driven estimation method for approximating network lifetimes for large-scale sensor networks where the optimization model becomes challenging, without replacing the existing model.

Keywords: wireless sensor network, grid-free WSNs, network lifetime maximization, optimization, mixed integer programming, Random Forest, machine learning

References

[1] Çelik, E., & Keskin, M. E. (2024). Izgara Olmayan Yapıda Kablosuz Sensör Ağ Tasarımı. 43. Yöneylem Araştırması ve Endüstri Mühendisliği Ulusal Kongresi, Trabzon, Türkiye, 2 - 04 Ekim 2024, ss.114.

[2] Çelik, E., & Keskin, M. E. (2026). Wireless sensor network design with reliable and long network lifetime. *Scientific Reports*. https://doi.org/10.1038/s41598-026-46014-x

[3] Çelik, E., Keskin, M. E., & Yiğit, V. (2025). Wireless Sensor Network Design in Grid-Free Structure. *Tehnički vjesnik*, *32*(5), 1798-1809. https://doi.org/10.17559/TV-20241211002189

✉ Corresponding Author Email: esracelik@atauni.edu.tr

Deep Learning Analysis of the Higgs Boson in de Sitter Space-Time Using PINN

Harun Selvitopi ✉

✉ *Erzurum Technical University, Department of Mathematic, Erzurum, Türkiye*

Abstract

The Higgs boson plays a fundamental role in the Standard Model of particle physics by providing a mechanism for mass generation through spontaneous symmetry breaking. Understanding the behavior of the Higgs field in curved space-time backgrounds is of considerable importance for modern cosmology, particularly in the context of the early universe where strong gravitational effects are expected to influence quantum fields. Among various cosmological geometries, de Sitter space-time represents an ideal framework for investigating particle dynamics during inflationary epochs due to its constant positive curvature and accelerated expansion.

In this study, we investigate the dynamics of the Higgs boson in de Sitter space-time using Physics-Informed Neural Networks (PINNs), a novel machine learning framework that integrates physical laws directly into the training process [1]. Unlike conventional numerical approaches, PINNs solve differential equations by minimizing a loss function that incorporates governing field equations, boundary conditions, and initial constraints. This methodology provides enables efficient treatment of complex physical systems characterized by nonlinearity and high-dimensional parameter spaces.

The mathematical formulation is based on the Klein–Gordon-type equation governing the evolution of the Higgs scalar field in a de Sitter background [2]. The de Sitter metric is incorporated into the field equations, and the resulting partial differential equation is embedded within the neural network architecture through automatic differentiation techniques. The PINN model is trained to approximate the Higgs field evolution while preserving the underlying conservation laws and geometric structure of curved space-time.

Numerical results demonstrate that the proposed PINN framework accurately captures the temporal and spatial behavior of the Higgs field under different cosmological expansion rates. Comparisons with benchmark numerical solutions reveal strong agreement and confirm the reliability of the PINN methodology. Furthermore, the study highlights the ability of PINNs to model field dynamics with reduced computational cost while maintaining high accuracy.

The findings suggest that physics-informed deep learning offers a powerful alternative for investigating quantum fields in curved backgrounds and may provide new insights into Higgs boson dynamics during the inflationary era of the universe. This work contributes to the growing intersection of artificial intelligence, cosmology, and high-energy physics, opening new opportunities for solving complex problems in theoretical and computational physics.

Keywords: PINN, Higgs Boson, de Sitter Space-Time

References

[1] Raissi, M., Perdikaris, P., & Karniadakis, G. E. (2019). Physics-informed neural networks: A deep learning framework for solving forward and inverse problems involving nonlinear partial differential equations. *Journal of Computational physics*, *378*, 686-707.

[2] Yagdjian, K. (2012). On the global solutions of the Higgs boson equation. *Communications in Partial Differential Equations*, *37*(3), 447-478.

✉ Corresponding Author Email: *harun.selvitopi@erzurum.edu.tr*

A Novel Entropy-SWARA Weighted Intuitionistic Fuzzy Hierarchical Clustering Framework for Sustainable Smart City Investment Prioritization

Ritu Bhuyan ✉, Juthika Mahanta

Department of Mathematics, National Institute of Technology Silchar, Assam, India

Abstract

Sustainable smart city investment requires advanced decision-support tools that consider the disagreement of stakeholders and multiple assessment dimensions while dealing with uncertainty simultaneously. The traditional multiple-criteria decision-making (MCDM) methods reduce assessment to a single numeric score, which neglects how alternatives are similar or dissimilar, making it difficult to establish coordinated investment strategies and identify project complements. In this study, a novel framework integrating entropy weighting, the Step-Wise Weight Assessment Ratio Analysis (SWARA) approach, and Intuitionistic fuzzy hierarchical clustering is proposed. The framework has three unique contributions. Firstly, we establish an entropy function considering linear and quadratic forms of changes in fuzzy membership to capture moderately fuzzy uncertain information more accurately. Secondly, we propose an arcsin-based similarity measure considering intuitionistic fuzzy values more suitably compared to the existing literature. Furthermore, we combine objective entropy weights and subjective SWARA weights via a multiplicative aggregation approach and finally apply the hierarchical clustering method to explore the structural similarity of alternatives. We examined the framework in a case study applied to Türkiye, where four sustainable smart city investment opportunities of smart grid modernization, sustainable public transportation, smart waste management, and smart healthcare infrastructure are evaluated by the domain experts based on 28 STEEP assessment criteria, which are social, technological, economic, environmental, and political ones [2]. The partition confidence interval is calculated as {0.0, 0.7725, 0.8383, 0.8510, 1.0}. The sustainable public transportation and smart health infrastructure show very complementary options (similarity score=0.851); therefore, they should be implemented in combination. Smart grid modernization stands alone among the four proposals, so a unique governance approach is needed. This study provides practical guidance for urban planners and policymakers on designing the structure of investment portfolios in support of the United Nations Sustainable Development Goals and makes progress toward bridging the gap between academic study and policy practice in sustainable urbanization.

Keywords: Intuitionistic Fuzzy set, Entropy, Smart city, Clustering, Sustainable computing.

References

[1] Atanassov, K. T. (1986). Intuitionistic fuzzy sets. *Fuzzy Sets and Systems*, *20*(1), 87–96. https://doi.org/10.1016/s0165-0114(86)80034-3

[3] Zeshui, X. (2009). Intuitionistic fuzzy hierarchical clustering algorithms. *Journal of Systems Engineering and Electronics*, *20*(1), 90-97.

[2] Yildirim, B., Ayyildiz, E., & Aydin, N. (2025). A strategic sustainability framework for smart city investment prioritization. *Sustainable Cities and Society*, *131*, 106705, https://doi.org/10.1016/j.scs.2025.106705.

✉ Corresponding Author Email*: ritu24_rs@math.nits.ac.in*

A Spatiotemporal Framework for Classifying Boarding Demand Among Passengers with Disabilities

Zeynep Nur Köstepen[1], Semiha Erkovan[1], Uğur Eliiyi[2]✉

[1] *İzmir Bakircay University, Department of Industrial Engineering, İzmir, Turkev*
[2] *İzmir Bakircay University, Department of Business, İzmir, Turkey*

Abstract

This study presents a temporal and spatial classification of travel demand among passengers with disabilities in a metropolitan urban centre by analysing one year of Electronic Fare Collection System boarding data involving a multimodal transportation system, including bus, tram, ferry and rail modes [1]. Following anonymization and data preprocessing, the study seeks to characterize regular and irregular travel behaviours, identify homogeneous passenger segments, and construct segment-based origin-destination matrices. The analytical framework combines descriptive statistics, time-series, density-based clustering and supervised machine learning methods [2]. Travel patterns are evaluated at different temporal resolutions to capture demand variability with greater precision. Model performance is assessed using standard classification and forecasting evaluation metrics [3]. Moreover, visualizations of how travel volumes vary across specific time periods, locations and passenger classes, will help decision makers to interpret model findings. By integrating spatiotemporal analysis with classification and segmentation techniques, a methodological basis for understanding the mobility needs of passengers with disabilities is provided. The analysis also considers differences between weekdays, weekends, peak hours, and off-peak periods to reveal when accessibility-oriented transport demand becomes more concentrated. In addition, spatial concentration patterns are examined to determine whether specific stops, transfer points, or urban corridors play a critical role for passengers. The expected outcomes include improved demand characterization and evidence to design a demand-responsive paratransit system. In this respect, the study contributes to the development of more inclusive and data-driven urban transport policies. These findings are expected to support route planning, service scheduling, and resource allocation decisions by providing empirically grounded evidence on mobility needs.

Keywords: Accessibility, Demand-responsive paratransit planning, Electronic fare collection data, Spatiotemporal analysis.

Acknowledgements

This study was supported under Project No. 125F309, supported by The Scientific and Technological Research Council of Türkiye (TÜBİTAK).

References

[1] Gordon, J., Koutsopoulos, H. N., Wilson, N. H. M., & Attanucci, J. 2018. "Automated inference of linked transit journeys in London using fare-transaction and vehicle location data", *Transportation Research Part C: Emerging Technologies*, 89, 56-75.

[2] Shi, Z., Shen, W., Schonfeld, P., Liu, Y., & Zhang, N. 2025. "Adaptive inference for dynamic passenger route usage patterns in a metro network considering time-varying and heavy-tailed travel times", *Transportation Research Part C: Emerging Technologies*, 171, 105007.

[3] Cats, O., Wang, Q., Zhao, Y. 2015. "Identification and classification of public transport activity centres in Stockholm using passenger flows data", *Journal of Transport Geography*, 48, 10-22.

✉ Corresponding Author Email: ugur.eliiyi@bakircay.edu.tr

A Genetic Algorithm for Resource Allocation and Scheduling in Agile Project Management: A Case Study

Elif Aydan Bike ✉, Betul Yagmahan

Bursa Uludag University, Industrial Engineering Department, Bursa, Türkiye

Abstract

Agile project management has become commonly used in the automotive sector following the software industry in recent years.In this study, the problem of assigning tasks to resources within sprint-based time periods in agile project management is investigated. The main objective of the problem is to minimize the total delay. During the task assignment process, sprint-based scheduling was carried out by considering capacity, time, and skill constraints. To solve the problem, the Genetic Algorithm was proposed. In addition, a real-life case study from an automotive company operating under a tender-based production system is presented. Since the projects are received through tenders, each project has predetermined "baseline start" and "baseline finish" dates. Along with the overall tender time constraint, jobs are assigned to sprints, and sprint-based job completion rates are considered highly important. Employees are divided into different groups and subgroups depending on their expertise, while the tasks included in the backlog are assigned to the appropriate subgroup according to employee qualifications. In addition to completing their assigned tasks on time, all subgroups are expected to follow the overall schedule to reduce tender delays. In the study, total delay, average tender delay, number of delayed tenders, total completion times, and different workload distributions were analyzed. The results indicated that the proposed genetic algorithm approach achieved better performance in minimizing total delay compared to the current planning results.

Keywords: Agile project management, resource allocation, genetic algorithm

References

[1] Kumar, A., Nagar, R., & Baghel, A. S. (2014, March). A genetic algorithm approach to release planning in agile environment. In 2014 International Conference on Information Systems and Computer Networks (ISCON) (pp. 118-122). IEEE.

[2] Ozcelikkan, N., Tuzkaya, G., Alabas-Uslu, C., & Sennaroglu, B. (2022). A multi-objective agile project planning model and a comparative meta-heuristic approach. Information and Software Technology, 151, 107023.

[3] Punyakum, V., Sethanan, K., Nitisiri, K., Pitakaso, R., & Gen, M. (2022). Hybrid differential evolution and particle swarm optimization for Multi-visit and Multi-period workforce scheduling and routing problems. Computers and Electronics in Agriculture, 197, 106929.

[4] Li, Y., Chen, X., An, Y., Zhao, Z., Cao, H., & Jiang, J. (2023). Integrating machine layout, transporter allocation and worker assignment into job-shop scheduling solved by an improved non-dominated sorting genetic algorithm. Computers & Industrial Engineering, 179, 109169.

✉ Corresponding Author Email: *512506003@ogr.uludag.edu.tr*

Robust and Sustainable Commercial Waste Collection with Inventory and Carbon Emission Constraints

Didem Eylenen✉, Bora Palandız, Mahmut Ali Gökçe

Yasar University, Industrial Engineering Department, İzmir, Turkey

Abstract

Efficient management of commercial solid waste collection processes has become a critical challenge due to rapid urbanization, strict operational limits, and carbon emission regulations. This study addresses an integrated Multi-Period Green Inventory Routing Problem (G-IRP) under demand uncertainty, balancing vehicle routing, multi-day waste accumulation, and load-dependent carbon emissions. Drawing on customer-based structures inspired by Solomon [1] and waste management dynamics [2], [3], the mathematical framework models waste accumulation over time through an inventory-routing mechanism, capturing inventory holding risks and overflow penalties [4], [5]. To address environmental sustainability concerns, the formulation incorporates a load-dependent carbon emission cap based on the pollution-routing framework of Bektaş and Laporte [6]. To safeguard the system against highly volatile waste generation rates without inducing excessive conservatism, the Γ budget robust optimization approach of Bertsimas and Sim [7] is incorporated to establish robust vehicle capacity buffers. Unlike traditional models that focus primarily on distance minimization, the proposed framework explicitly incorporates service quality considerations through soft time windows, allowing penalties for both early and late arrivals. A Mixed-Integer Linear Programming (MILP) model is created and solved on a synthetic commercial waste collection instance that has 20 customers, using Python and the Gurobi Optimizer. Computational scenario analyses conducted under different demand and uncertainty settings demonstrate that the robust framework successfully improves the robustness of waste collection schedules against unexpected overflows and route failures, providing critical managerial insights into the trade-offs between fleet scaling, operational costs, and strict environmental compliance.

Keywords: Commercial Waste Collection, Inventory Routing, Robust Optimization

References

[1] Solomon, M. M. (1987). Algorithms for the vehicle routing and scheduling problems with time window constraints. Operations Research, 35(2), 254–265.
[2] Kim, B. I., Kim, S., & Sahoo, S. (2006). Waste collection vehicle routing problem with time windows. Computers & Operations Research, 33(12), 3624–3642.
[3] Bautista, J., Fernández, E., & Pereira, J. (2013). Solving an urban waste collection problem using metaheuristics. Computers & Operations Research, 40(7), 1737–1749.
[4] Johansson, O. M. (2006). The effect of dynamic scheduling and routing in a solid waste management system. Waste Management, 26(8), 875–885.
[5] Mes, M., Schutten, M., & Rivera, A. P. (2014). Inventory routing for dynamic waste collection. Waste Management, 34(9), 1564–1576.
[6] Bektaş, T., & Laporte, G. (2011). The pollution-routing problem. Transportation Research Part B: Methodological, 45(8), 1232–1250.
[7] Bertsimas, D., & Sim, M. (2004). The price of robustness. *Operations Research*, 52(1), 35–53.

✉ Corresponding Author Email: didem.eylenen@yasar.edu.tr

A Computational Study of Parameter-Dependent Magnetohydrodynamic Flows

Canan Bozkaya✉

Middle East Technical University, Mathematics Department, Ankara, Turkey

Abstract

Magnetohydrodynamic (MHD) flows play an important role in numerous engineering and industrial applications involving electrically conducting fluids under the influence of magnetic fields, including energy systems, cooling technologies, and electromagnetic control processes [1]. These flows are particularly relevant in modern high-performance engineering systems where magnetic regulation of fluid motion is used to enhance efficiency and stability. The strong coupling between fluid motion and electromagnetic effects gives rise to complex mathematical models whose solutions are highly sensitive to the governing physical and boundary-condition parameters [1]. In this study, parameter-dependent MHD flow problems are investigated through numerical simulations generated for a range of Hartmann numbers and boundary-condition parameters, allowing a systematic exploration of magnetic and hydrodynamic interactions. Such parametric variations enable a detailed understanding of flow transitions between different regimes and provide insight into the underlying physical mechanisms. The resulting solution data are analyzed in detail to identify the dominant flow characteristics and to examine the influence of the governing parameters on the velocity and magnetic field distributions across different flow regimes. To improve computational efficiency and facilitate rapid evaluation of parameter-dependent solutions, reduced-order modeling strategies are further explored for constructing compact yet accurate representations of the solution manifold [2,3]. The proposed approach combines accurate numerical simulations with efficient surrogate modeling, providing both physical insight and computational advantages for the analysis of MHD flows. The methodology is sufficiently general to be adapted to different MHD configurations and parameter regimes, while providing an effective tool for the analysis, approximation, and prediction of parameter-dependent MHD flows.

Keywords: Magnetohydrodynamics, parametric analysis, model reduction.

References

[1] Davidson, P.A. (2001). Introduction to Magnetohydrodynamics. Cambridge University Press.
[2] Benner, P., Ohlberger, M., Cohen, A., and Willcox, K. (2017). Model Reduction and Approximation: Theory and Algorithms. SIAM, Philadelphia.
[3] Rowley, C. W., & Dawson, S. T. M. (2017). Model Reduction for Flow Analysis and Control. Annual Review of Fluid Mechanics, *49*, 387-417.

✉ Corresponding Author Email: *bcanan@metu.edu.tr*

A Simulation–Optimization Framework for Multi-Elevator Systems Using Polling Models and Hyperparameter Tuning

Berkin Yeginoğlu[1]✉, Ayhan Özgür Toy[2]

[1] *Yasar University, Yasar University Graduate School, İzmir, Türkiye*
[2] *Yasar University, Industrial Engineering Department, İzmir, Türkiye*

Abstract

Elevator systems constitute complex stochastic service environments in which multiple elevators simultaneously respond to passenger requests originating from different floors. The performance of such systems depends not only on dispatching algorithms but also on strategic operational decisions, including idle dwelling locations and zoning configurations [1]. "Dwelling" determines the floor at which an elevator remains stationed when no service requests are present, thereby influencing future response times, whereas "zoning" specifies the subset of floors assigned to each elevator. Determining effective combinations of these control policies is challenging due to the dynamic and stochastic nature of passenger demand.

This study models a multi-elevator system as a multiple-queue multiple-server polling system and develops an agent-based simulation framework to evaluate operational performance under realistic conditions [2]. Passenger arrivals are represented by stochastic processes, while customer impatience is incorporated through reneging behavior, allowing passengers to abandon the system after experiencing excessive waiting times [3]. Within the proposed framework, elevators operate according to two widely used polling disciplines, namely SCAN and LOOK, while elevator-specific idle dwelling locations and zoning assignments are treated as controllable decision variables. To identify high-performing operational policies, a Bayesian hyperparameter optimization approach is employed to simultaneously tune dwelling and zoning decisions for each elevator [4]. The main novelty of this study lies in the joint integration of *(i)* a polling-based multi-queue multi-server representation of elevator systems, *(ii)* explicit modeling of customer reneging and bulking within a multi-elevator environment, and *(iii)* the use of Bayesian hyperparameter optimization to simultaneously learn elevator-specific dwelling and zoning policies.

Computational study is conducted to compare dispatching policies and assess the impact of optimized control configurations. The results demonstrate that dispatching policies alone are insufficient to achieve superior system performance. Significant improvements are obtained when dispatching strategies are combined with optimized dwelling and zoning decisions.

Keywords: discrete-event simulation, queueing theory, parameter optimization

References

[1] Barney, G.C., & dos Santos, S.M. (2015). Elevator Traffic Handbook: Theory and Practice. 2nd ed. Routledge, London.
[2] Takagi, H. (1988). Queueing analysis of polling models. ACM Computing Surveys, 20(1), 5–28.
[3] Ancker, C.J., & Gafarian, A.V. (1963). Some queuing problems with balking and reneging – I. Operations Research, 11(1), 88–100.
[4] Shahriari, B., Swersky, K., Wang, Z., Adams, R.P., & De Freitas, N. (2016). Taking the human out of the loop: A review of Bayesian optimization. Proceedings of the IEEE, 104(1), 148–175.

✉ Corresponding Author Email: *berkin.yeginoglu@yasar.edu.tr*

Energy and Carbon Intensity Performance of BIST Sustainability Firms: A Multi-Period MCDM Approach

Cansu Aksu[1]✉, Gülşen Yaman[2], Ramazan Yaman[3]

[1] *Zonguldak Bülent Ecevit University, Business Administration Department, Zonguldak, Turkey*
[2] *Balıkesir University, Mechanical Engineering Department, Balıkesir, Turkey*
[3] *Balıkesir University, Industrial Engineering Department, Balıkesir, Turkey*

Abstract

This study evaluates the energy and carbon intensity performance of non-financial firms included in the BIST Sustainability framework over the 2022-2024 period using a multi-period multi-criteria decision-making approach. Financial institutions and holding companies are excluded because their operational energy consumption and emission structures are not directly comparable with those of industrial, transportation, retail, telecommunications, and other energy-related firms. The final sample consists of firms disclosing total energy consumption, Scope 1 emissions, Scope 2 emissions, and net sales for all three years.

Three cost-oriented indicators are constructed to capture operational efficiency and carbon-related performance. Energy intensity is measured as total energy consumption divided by net sales. Emission intensity is measured as the sum of Scope 1 and Scope 2 emissions divided by net sales. Carbon intensity of energy use is measured as the sum of Scope 1 and Scope 2 emissions divided by total energy consumption [1]. Since lower values indicate better performance, the analysis focuses on efficiency-oriented sustainability performance rather than broad ESG scores. Criterion weights are determined objectively using the Entropy method, while firm-level performance scores are calculated through MARCOS by considering ideal and anti-ideal reference solutions [2]. EDAS is then applied as an alternative ranking procedure based on distances from the average solution [3]. Spearman rank correlation analysis examines method-based ranking consistency and year-to-year ranking stability.

The study contributes to the literature by proposing a transparent and reproducible framework based on directly measurable quantitative sustainability disclosures. The findings are expected to provide insights for managers, investors, and policymakers interested in energy efficiency, carbon performance, and disclosure comparability in emerging markets.

Keywords: Energy intensity, Carbon intensity, BIST Sustainability, Multi-criteria decision-making.

References

[1] International Sustainability Standards Board. (2023). IFRS S2 Climate-related Disclosures. IFRS Foundation. Available from: https://www.ifrs.org/content/dam/ifrs/publications/pdf-standards-issb/english/2023/issued/part-a/issb-2023-a-ifrs-s2-climate-related-disclosures.pdf?bypass=on [Accessed 4 May 2026].

[2] Stević, Ž., Pamučar, D., Puška, A., & Chatterjee, P. (2020). Sustainable supplier selection in healthcare industries using a new MCDM method: Measurement of Alternatives and Ranking according to COmpromise Solution (MARCOS). Computers & Industrial Engineering, 140, 106231.

[3] Keshavarz-Ghorabaee, M., Zavadskas, E.K., Olfat, L., & Turskis, Z. (2015). Multi-Criteria Inventory Classification Using a New Method of Evaluation Based on Distance from Average Solution (EDAS). Informatica, 26, 435-451.

✉ Corresponding Author Email: *cansuaksu@beun.edu.tr*

Double Local Fractional Natural Transform Approach for Fractional Partial Differential Equations

Mountassir Hamdi Cherif[1]✉, Djelloul Ziane[2], Dumitru Baleanu[3], Hassan Kamil Jassim[4], Taylan Demir[5]

[1] *Laboratory of Complex Systems, Higher School of Electrical and Energetic Engineering of Oran, Oran, Algeria*
[2] *Department of Mathematics, Faculty of Mathematics and Material Sciences, Kasdi Merbah University of Ouargla, Ouargla, Algeria*
[3] *Department of Computer Science and Mathematics, Lebanese American University, Beirut, Lebanon*
[4] *Department of Mathematics, College of Education for Pure Science, University of Thi-Qar, Nasiriyah, Iraq*
[5] *Department of Mathematics, Ankara University, Ankara, Turkey*

Abstract

The use of fractional PDEs has increased due to their applicability in describing mathematical models associated with the presence of fractal structure, anomalous diffusion, and non-differentiability. Local fractional calculus has become a powerful tool used to model physical processes occurring in fractal sets [1]. Transformation method techniques continue to be powerful methods for solving differential equations in engineering and applied mathematics. In particular, the natural transform and its extended form have proven to be powerful methods for solving multidimensional problems [2]. In the present work, we propose a new transform named double local fractional natural transform which is introduced through generalization of classical double natural transform into the realm of local fractional calculus. Double local fractional natural transform is formulated using double local fractional integrals along with well defined mathematical concepts of local fractional derivative and local fractional integral. Some basic properties of the transform such as linearity, local fractional partial derivative operational properties, convolution and transformation formulae for some special functions are derived. The efficiency of the suggested technique is justified with the help of its implementation on several important categories of local fractional partial differential equations such as local fractional heat, Laplace, wave and Klein-Gordon equations. Closed-form solutions are obtained and are observed to match those already available in the literature [2,3]. The approach that we have adopted here converts differential equations into algebraic equations. From the above discussion on the outcomes realized, it can be deduced that the double local fractional natural transform proves to be a very efficient technique for handling local fractional partial differential equations. The above framework may prove useful in further research work concerning fractal media and anomalous diffusion, among others.

Keywords: Local fractional calculus, Natural transform, Double integral transforms, fractional partial differential equations, fractal modelling.

References

[1] Yang, X. J. (2012). Local fractional integral equations and their applications. *Advances in Computer Science and its Applications (ACSA)*, *1*(4).
[2] Kilicman, A., & Omran, M. (2017). On double Natural transform and its applications. *J. Nonlinear Sci. Appl*, *10*(4), 1744-1754.
[3] Ziane, D., & Cherif, M. H. The local fractional natural transform and its applications to differential equations on Cantor sets.

✉ Corresponding Author Email: *demir.taylan96@gmail.com*

Common Due Date Assignment and Scheduling for Unrelated Parallel Machines

Helin Su Acar[1]✉, Önder Bulut[2], Ayhan Özgür Toy[2]

[1] *Yasar University, Yasar University Graduate School, İzmir, Türkiye*
[2] *Yasar University, Industrial Engineering Department, İzmir, Türkiye*

Abstract

Due date assignment problem in scheduling plays a critical role in production systems where Just-in-Time production philosophy and customer satisfaction are considered simultaneously. In such systems, assigning due dates and determining effective job schedules are essential decisions in order to reduce operational costs composed of earliness, tardiness, and due date assignment costs. In this study, we consider the minimization of total weighted earliness, tardiness, and due date assignment costs as the objective function.

Although this problem has been widely studied for single and identical parallel machine environments, studies are limited for unrelated parallel machine settings, where each job has a machine-dependent processing time. Two of these studies stand out: [1] and [2]. In [1], an algorithm based on the structural properties of the optimal solution is proposed. Despite the use of structural properties, this algorithm is a rule-based myopic algorithm that constructs a single solution. Later, in [2], a genetic algorithm which does not consider the structural properties of the optimal solution in their solution representation is presented, and it is shown that their algorithm outperforms the algorithm proposed in [1].

To eliminate the disadvantages of the existing algorithms, in this study, a new genetic algorithm is proposed by incorporating the structural properties of the optimal solution into the main components of the algorithm. The initial population is generated through constructive heuristics to obtain promising initial solutions. In addition, the chromosome structure, crossover operator, and mutation operator are designed based on the structural properties of the problem. A preliminary experimental study shows that the proposed algorithm explores the solution space more effectively.

Keywords: Unrelated parallel machines, common due date assignment, heuristics, genetic algorithm

References

[1] Adamopoulos, G. I., & Pappis, C. P. (1998). Scheduling under a common due-data on parallel unrelated machines. European Journal of Operational Research, 105(3), 494-501.

[2] Min, L., & Cheng, W. (2006). Genetic algorithms for the optimal common due date assignment and the optimal scheduling policy in parallel machine earliness/tardiness scheduling problems. Robotics and computer-integrated manufacturing, 22(4), 279-287.

✉ Corresponding Author Email: *helin.acar@yasar.edu.tr*

A Deep Learning Synchronizer for Fractional-Order Chaotic Secure Communication: Application to Renewable-Energy-Based Electric Vehicle Charging Stations

Haris Calgan[1,2]✉, Metin Demirtas[1], Suleiman M. Sharkh[2]

[1] *Balikesir University, Department of Electrical and Electronics Engineering, Balikesir, 10145, Türkiye*
[2] *University of Southampton, Mechatronics Research Group, Southampton, SO171BJ, United Kingdom*

Abstract

The increasing deployment of renewable-energy-based electric vehicle charging stations (EVCSs) has introduced significant cybersecurity challenges due to the extensive exchange of control and monitoring data over communication networks [1]. Conventional chaos-based secure communication schemes commonly rely on analytical synchronization controllers, which increase computational burden and require continuous transmission of control-related information [2]. To address these limitations, this paper proposes a novel deep learning-based synchronization framework for fractional-order chaotic secure communication. The proposed method eliminates the need for a predefined controller by employing a deep learning model to predict the control signal for synchronization directly from transmitted chaotic states and synchronization errors. A fractional-order chaotic system is utilized to generate secure masking signals, while a Long Short-Term Memory (LSTM) network learns the synchronization dynamics and estimates the required control action in real time. The synchronized chaotic states are subsequently employed for masking of critical EVCS communication signals. The effectiveness of the proposed framework is evaluated under various operating conditions. Simulation results demonstrate that the AI-based synchronizer achieves accurate chaotic synchronization while reducing controller complexity and maintaining secure data transmission. The proposed approach introduces a new paradigm that combines artificial intelligence and fractional-order chaos for cyber-secure operation of renewable-energy-integrated electric vehicle charging infrastructures.

Keywords: Fractional-order chaotic systems; Deep learning; LSTM; Chaotic synchronization; Secure communication; Electric vehicle charging stations; Renewable energy systems.

Acknowledgements

H.C. thanks the TUBITAK BIDEB-2219 program for a postdoctoral grant (1059B192400296).

References

[1] Razaghi, F. (2026, January). Renewable Energy-Based Charging Infrastructure for Electric Vehicles: A Review. In 2026 IEEE Electrical Energy Storage Applications and Technologies Conference (EESAT) (pp. 1-5). IEEE. Mercer, P.A., & Smith, G. (1993). Private Viewdata in the UK. 2nd ed. Longman, London.

[2] Demirtas, M., Sharkh, S. M., Gokyildirim, A., & Calgan, H. (2025). Secure operation of a stand-alone wind energy system based on an incommensurate fractional-order chaotic system. Applied Energy, 384, 125477.

✉ Corresponding Author Email: haris.calgan@balikesir.edu.tr, haris.calgan@soton.ac.uk

Fuzzy-Enhanced Synergy-Driven R&D Project Portfolio Selection under Uncertainty: A Distributionally Robust and Cooperative Game-Theoretic Framework

Ulviye Savaş✉, Vildan Özkir, Selçuk Alp

Yıldız Technical University, Industrial Engineering Department, İstanbul, Türkiye

Abstract

This study proposes a two-stage integrated decision-support model for R&D project portfolio selection, addressing uncertainty, inter-project synergy, and cost allocation within a unified framework. In the first stage, candidate projects are evaluated in terms of cost, risk, duration, workforce requirements, and strategic benefit, and the most suitable project portfolio is selected. Cost and risk uncertainties are modeled through distributionally robust optimization, while uncertainties related to project duration and workforce requirements are represented using a budget-of-uncertainty approach. In the proposed framework, the synergy among projects is first evaluated linguistically by experienced project experts and then transformed into coalition-specific cost-saving parameters through fuzzy number-based calculations. These evaluations consider resource sharing, technological complementarity, knowledge transfer, output compatibility, and temporal coordination. In the illustrative application, seven candidate projects are considered, and 120 possible coalitions consisting of two or more projects are evaluated using triangular fuzzy numbers, trapezoidal fuzzy numbers, and (p,q)-fractional fuzzy numbers. The resulting synergy values are used as inputs in the first-stage portfolio selection model. After the portfolio is selected, the second stage allocates the net portfolio cost among the selected projects by using the core concept of cooperative game theory, thereby ensuring a fair and stable cost-sharing scheme. The proposed framework supports reliable project selection under uncertainty, transparent quantification of inter-project synergies, and practically implementable cost allocation for the selected portfolio.

Keywords: Project portfolio selection, fuzzy synergy calculation, cooperative game theory, distributionally robust optimization, budget of uncertainty, core, cost allocation.

References

[1] Archer, N.P., & Ghasemzadeh, F. (1999). An integrated framework for project portfolio selection. International Journal of Project Management, 17(4), 207–216.

[2] Asgari, S., & Afshar-Nadjafi, B. (2020). A bi-objective model for project portfolio selection problem with synergy and risk considerations using cooperative game theory. Journal of Project Management, 5(4), 225–236.

[3] Asgari, S., Afshar, A., & Madani, K. (2014). Cooperative game theoretic framework for joint resource management in construction. Journal of Construction Engineering and Management, 140(5), 04013066.

[4] Ashrafi, M., Davoudpour, H., & Abbassi, M. (2012). Developing a decision support system for R&D project portfolio selection with interdependencies. AIP Conference Proceedings, 1499(1), 370–378. https://doi.org/10.1063/1.4769016

[5] Bai, L., Qu, X., Wang, X., Zhang, L., & Yang, J. (2024). Project portfolio selection with relationship considerations: A random walk with restart based on influencing factors. Computers & Industrial Engineering, 198, 110718. https://doi.org/10.1016/j.cie.2024.110718

[6] Bai, L., Yang, M., Pan, T., & Sun, Y. (2025). Project portfolio selection and scheduling incorporating dynamic synergy. Kybernetes, 54(2), 996–1026. https://doi.org/10.1108/K-04-2023-0694

[7] Bai, L., Zhang, L., Zhang, L., Shao, K., & Luo, X. (2025). Unlocking the potential of project portfolio: Value-oriented interactive risk management. Humanities and Social Sciences Communications, 12, Article 1012. https://doi.org/10.1057/s41599-025-05296-8

✉ Corresponding Author Email: *ulviyesavas@gmail.com; ulviye.savas@std.yildiz.edu.tr*

Dirac magnetic monopole: The MICZ–Kepler problem as a subset of the Bağcı–Hoggan differential equation

Zühra Güneş ✉, Ali Bağcı

Pamukkale University, Physics Department, Denizli, Türkiye

Abstract

Magnetic monopoles play an important role in modern theoretical physics through their connection to charge quantization and gauge symmetry. Electrodynamics and quantum mechanics of the magnetic monopole are briefly re-visited. The MICZ–Kepler problem, which describes the motion of a charged particle in the combined Coulomb and monopole fields is discussed. It is shown that the radial equation of the generalized MICZ–Kepler system constitutes a special case of the fractional Bağcı–Hoggan differential equation for a specific choice of parameters.

Keywords: Dirac magnetic monopole, MICZ–Kepler problem, Bağcı–Hoggan differential equation.

References

[1] Bağcı A., Hoggan P. E. (2023). Complete and orthonormal sets of exponential-type orbitals with non-integer quantum numbers. Journal of Physics A: Mathematical and Theoretical, 56(33), 335205.
[2] Mardoyan L. (2003). The generalized MIC-Kepler system. Journal of Mathematical Physics, 44(11). 4981-4987.
[3] Meng W (2007). MICZ-Kepler problems in all dimensions. Journal of Mathematical Physics, 48(3). 032105.

✉ Corresponding Author Email: *gunesz.chem@gmail.com*

A Multi-Commodity Flow Optimisation Model for Sustainable Port–Hinterland Freight Transport Planning

Seyma Mercan✉, Cagatay Iris, Dongping Song

University of Liverpool, Management School, Liverpool, United Kingdom

Abstract

Sustainable port–hinterland freight transport has become an increasingly important component of transport decarbonisation strategies, as environmental impacts extending beyond the port gate into hinterland transport networks are significant and challenging to address. Existing studies have examined a range of operational, technical, and market-based measures to improve environmental performance across the broader maritime transport industry [1]. However, the role of ports in addressing environmental impacts within hinterland transport systems has received comparatively less attention in the literature [2].

Freight transportation planning and service network design have long been studied in the logistics literature [3,4]. In this context, optimisation-based approaches have been applied to intermodal network planning and freight transport systems [4,5]. However, limited attention has been given to optimisation frameworks that explicitly support sustainability-oriented decision-making in port–hinterland freight transport systems. Building on this stream of research, this study presents a multi-commodity flow optimisation model for port–hinterland freight transport planning that explicitly considers sustainable performance. The model represents freight movements between a seaport and multiple hinterland destinations through an intermodal transport network with alternative transport modes and intermediate terminal connections.

The model provides a basis for analysing how freight flows can be distributed across road, rail, and inland waterway transport options within port–hinterland systems. The proposed framework aims to support sustainable port–hinterland freight transport planning by facilitating the evaluation of modal-shift strategies and policy-based interventions.

Keywords: Port–hinterland transport, Multi-commodity flow optimisation, Sustainable freight transport planning

References

[1] Song, D. (2024). A literature review of seaport decarbonisation: Solution measures and roadmap to net zero. *Sustainability, 16*(4), 1620. https://doi.org/10.3390/su16041620

[2] Gonzalez Aregall, M., Bergqvist, R., & Monios, J. (2018). A global review of the hinterland dimension of green port strategies. *Transportation Research Part D: Transport and Environment, 59*, 23–34. https://doi.org/10.1016/j.trd.2017.12.013

[3] Crainic, T. G. (2000). Service network design in freight transportation. *European Journal of Operational Research, 122*(2), 272–288. https://doi.org/10.1016/S0377-2217(99)00233-7

[4] Crainic, T. G., & Kim, K. H. (2007). Intermodal transportation. In C. Barnhart & G. Laporte (Eds.), *Handbooks in Operations Research and Management Science: Transportation* (Vol. 14, pp. 467–537). Elsevier. https://doi.org/10.1016/S0927-0507(06)14008-6

[5] Zhang, M., Janic, M., & Tavasszy, L. A. (2015). A freight transport optimisation model for integrated network, service, and policy design. *Transportation Research Part E: Logistics and Transportation Review, 77*, 61–76. https://doi.org/10.1016/j.tre.2015.02.013

Corresponding Author Email: *mercanseyma@gmail.com*

A Structural Aspect of Module Classes

Ebru Açikgöz[1] ✉, Semra Doğruöz[2]

[1] *Aydın Adnan Menderes University, Graduate School of Natural and Applied Sciences, Aydin, Türkiye*
[2] *Aydın Adnan Menderes University, Science Faculty, Department of Mathematics, Aydin, Türkiye*

Abstract

Module theory provides a fundamental framework for studying algebraic structures and their interactions through homomorphisms and categorical methods. The investigation of module classes and their structural properties has long been an important topic in modern algebra, particularly in relation to closure properties and preservation under various module-theoretic constructions.

In this study, we consider a class of modules arising naturally in module theory and examine several aspects of its structural behavior. The primary objective is to investigate how the considered class behaves under commonly used constructions and to determine conditions ensuring the preservation of its defining properties. Particular attention is devoted to the relationships between the class of injective modules and divisible module classes.

Several structural properties are analyzed through direct sums, homomorphic images, and extensions. These constructions play a central role in understanding the stability of algebraic properties and provide valuable information concerning the behavior of modules under categorical operations. Furthermore, the interaction between different structural conditions is discussed, leading to a broader perspective on the classification of modules.

The obtained observations contribute to the understanding of module classes from both algebraic and categorical viewpoints. In addition, the methods employed provide a useful framework for the investigation of related algebraic structures and for the development of further studies concerning structural properties of modules. The results highlight the significance of closure conditions and categorical techniques in the analysis of module-theoretic phenomena.

Keywords: Module classes, algebraic structures, divisibility

References

[1] Anderson, F. W., and K. R. Fuller. (1992). *Rings and Categories of Modules*. Springer.
[2] P. E. Bland. (1974). *Divisible and codivisible modules,* Math. Scand. *34* 153-161.
[3] Faith, C. (1967). *Lectures on Injective Modules and Quotient Rings*. Springer LNM 49.
[4] Lam, T. Y. (1999). *Lectures on Modules and Rings*. Springer.

✉ Corresponding Author Email: *2410500102@stu.adu.edu.tr*

Ranking Syrian Governorates Based on Humanitarian Sectoral Needs Using an Entropy-Based MOORA Approach

Meryem Abdullahaljouma✉, Ömer Nedim Kenger, Süleyman Mete

Gaziantep University, Industrial Engineering Department, Gaziantep, Turkey

Abstract

Humanitarian response planning requires transparent and data-driven methods to identify areas with the highest level of need, especially in crises where needs are diverse and resources are limited. This study uses sectoral People in Need (PiN) data produced by OCHA and humanitarian partners using the Joint Intersectoral Analysis Framework (JIAF) [1] to support governorate-level humanitarian prioritization in Syria through an Entropy-based MOORA approach. The governorates are considered as alternatives, while humanitarian sectors, including protection, food security, WASH, shelter, nutrition, health, education, early recovery, and non-food items, are treated as decision criteria. In the first stage, the entropy method is applied to calculate objective weights for the criteria by measuring the degree of variation among governorates within each sector. The results show that NFI has the highest weight, followed by shelter, suggesting that these sectors have strong discriminating power in explaining differences in humanitarian needs across governorates. In the second stage, the MOORA method is used to rank the governorates based on the weighted sectoral criteria. The obtained ranking is then compared with the ranking based on Inter-sectoral People in Need, which is estimated using the Mosaic Method [2]. The results show agreement in the top five priority governorates, namely Aleppo, Idleb, Rural Damascus, Al-Hasakeh, and Deir-ez-Zor, while differences appear among the middle-ranked governorates. These differences suggest that the proposed approach captures sectoral variations that may be hidden in aggregated indicators. Therefore, the Entropy-based MOORA approach can supplement existing humanitarian prioritization tools and provide a more detailed, transparent, and data-driven framework for supporting humanitarian decision-making and resource allocation in Syria effectively.

Keywords: Humanitarian prioritization, Entropy method, MOORA

References

[1] OCHA Syria. (2025). Syrian Arab Republic: JIAF Humanitarian Needs and Severity Data [online]. Humanitarian Data Exchange. Available from: https://data.humdata.org/dataset/syr-jiaf-humanitarian-needs-pin-and-severity [Accessed 10 June 2026].

[2] JIAF. (2024). Joint and Intersectoral Analysis Framework (JIAF) 2 Technical Manual [pdf]. OCHA. Available from: https://www.unocha.org/attachments/7d1f1edc-e128-42fd-a895-cb924dbb0aa5/JIAF-2-Technical-Manual_Final-for-2025-HPC.pdf

✉ Corresponding Author Email: *maryamabd912@gmail.com*

A Nonlinear Median Filter Regularization Operator for Geophysical Inversion

Oya Tarhan Bal, Gökhan Karcıoğlu✉

Istanbul University-Cerrahpasa, Geophysical Engineering Department, Istanbul, Turkiye

Abstract

Geophysical inverse problems involve estimating the spatial distribution of subsurface physical properties, such as electrical resistivity, density, magnetic susceptibility, and seismic velocity, from observed data. These problems are typically ill-posed, nonlinear, and underdetermined, requiring regularization to obtain stable and meaningful solutions. The most commonly used approach is Tikhonov regularization, which employs derivative-based roughening operators to penalize differences between neighboring model parameters and promote spatial smoothness.

Although effective in stabilizing the inversion process, conventional roughening operators tend to oversmooth the recovered models and suppress sharp contrasts, resulting in poor resolution of geological boundaries. To overcome this limitation, we propose a nonlinear regularization operator inspired by the median filter [1] widely used in image processing. The proposed operator retains the structure of a traditional roughening matrix but adaptively reweights its coefficients using a Gaussian function based on the deviation of each model parameter from the median value within its local neighborhood. This strategy reduces smoothing across discontinuities while preserving the stability of the inversion.

The proposed regularization scheme is incorporated into a standard iterative inversion framework and evaluated using both synthetic and field datasets. Results from 2D and 3D tomographic imaging examples demonstrate improved recovery of sharp subsurface boundaries and enhanced model resolution compared with conventional smoothness-constrained inversion. These findings suggest that median filter based regularization provides an effective alternative for geophysical inverse problems.

Keywords: geophysical inverse problem, regularization, median filter

References

[1] Tarhan Bal, O., & Karcioglu, G. (2025). Three-Dimensional Inversion of Gravity Data Using the Levy PDF for Depth Weighting and a Rank Order Smoothing Constraint. Mathematical Geosciences, 57(3), 523-545.

✉ Corresponding Author Email: *gkarci@iuc.edu.tr*

Life Cycle Cost and Emission-Based Multi-Objective Optimization of Net-Zero Renewable Energy Microgrids

Elif Tarakçı✉

Istanbul Atlas University, Department of Industrial Engineering, Istanbul, Türkiye

Abstract

The growing importance of decarbonization goals and the transition from centralized energy systems to distributed energy structures have increased interest in microgrid systems that support net-zero energy targets. This study proposes a multi-objective optimization and mathematical modeling approach for the planning of renewable energy-based microgrids. The developed model simultaneously addresses the assessment of renewable energy potential at predefined candidate locations, the allocation of appropriate energy technologies, the determination of system capacities, and the sizing of energy storage systems (ESS). The primary objective of the proposed framework is to minimize life cycle cost (LCC) and life cycle carbon emissions (LCE) under net-zero energy targets. To achieve this, various renewable energy technologies, energy storage systems, and their associated life cycle impacts, including investment, operation, maintenance, replacement, and end-of-life stages, are taken into consideration. Using geographical data, energy demand profiles, and meteorological time series, the renewable energy potential of each location is evaluated, and the optimal technology mix and storage capacity are determined. The mathematical model is solved under constraints related to system reliability, supply–demand balance, and net-zero energy requirements. The proposed approach provides an integrated decision-support framework for decision-makers involved in the planning and design of sustainable microgrid systems under net-zero energy targets.

Keywords: modelling and optimization, renewable energy-based microgrids, life cycle assessment, net-zero energy systems, technology allocation

References

[1] Kerem, A. (2022). Investigation of carbon footprint effect of renewable power plants regarding energy production: A case study of a city in Turkey. Journal of the Air & Waste Management Association, 72(3), 294–307.

[2] Das, U., & Nandi, C. (2025). Life cycle assessment of wind farm: A review on current status and future knowledge. Energy and Climate Change, 6, 100206.

[3] Moussavi, S., Barutha, P., & Dvorak, B. (2023). Environmental life cycle assessment of a novel offshore wind energy design project: A United States based case study. Renewable and Sustainable Energy Reviews, 185, 113643.

[4] Ibrahim, H.A., & Thopil, G.A. (2025). Life cycle assessment of external impacts and external costs of a potential offshore wind farm off the Southern African coast. Energy, 335, 138382.

[5] Faizan, M., & Afgan, I. (2026). Life cycle assessment of wind turbine systems: A statistical synthesis approach to address greenhouse gas emissions. Renewable and Sustainable Energy Reviews, 226, 116429.

✉ Corresponding Author Email: *elif.tarakci@atlas.edu.tr*

Blockchain-Integrated Life Cycle Carbon Footprint Management and Decision Support Model for Solar Power Plants

Gülşen Yaman[1], Suat Onur[2], Elif Tarakçı[3], Ramazan Yaman[4]✉

[1] *Balikesir University, Faculty of Engineering, Mechanical Engineering Dept., Balıkesir, Türkiye*
[2] *Balikesir University, Department of Informatics, Balıkesir, Türkiye*
[3] *Istanbul Atlas University, Faculty of Engineering and Natural Sciences, Industrial Eng.Dept., Istanbul, Türkiye*
[4] *Balikesir University, Faculty of Engineering, Industrial Engineering Dept., Balıkesir, Türkiye*

Abstract

While Solar Power Plants (SPP) hold a strategic position in sustainable energy supply, determining their net environmental benefits necessitates a precise calculation of the total carbon footprint within a "cradle-to-grave" Life Cycle Assessment (LCA) framework. Current literature highlights that emission tracking during the installation and operational phases is often hindered by data silos and a lack of transparency, while the decommissioning phase of systems reaching the end of their economic life is frequently excluded from dynamic modeling processes. This study develops an end-to-end carbon footprint calculation and decision support model that holistically addresses the construction, active operation, and decommissioning phases of SPP investments. To ensure data integrity, immutability, and retrospective traceability of the proposed model, a decentralized blockchain architecture and smart contract infrastructure have been designed, providing a secure and verifiable emission accounting ecosystem for both investors and regulatory authorities. The sectoral feasibility and performance of the developed approach under various constraints have been validated through comprehensive case studies and simulations involving diverse SPP installation, operation, and disposal parameters.

Keywords: Solar Power Plants, Carbon Footprint, Life Cycle Assessment (LCA), Blockchain, Smart Contracts, Decision Support Systems

References

[1] Luo, J., Yang, H., Zhang, L., Liu, H., Wang, Y., & Hao, C. (2024). A comparative study on the combination of life cycle assessment and ecological footprints: solar photovoltaic power generation vs. coal power generation. Frontiers in Energy Research, 12, 1375820.
[2] Patro, P. K., Jayaraman, R., Acquaye, A., Salah, K., & Musamih, A. (2025). "Blockchain-based solution to enhance carbon footprint traceability, accounting, and offsetting." International Journal of Production Research, 1-34.
[3] Farahani, J. V. & Treiblmaier, H. (2025). A Sustainability Assessment of a Blockchain-Secured Solar Energy Logger for Edge IoT Environments. Sustainability, 17(17), 8063.

✉ Corresponding Author Email: *ryaman@balikesir.edu.tr*

Local Stability and Hopf Bifurcation in a Three-Dimensional Photocatalytic Microplastic Reactor Model with Adaptive Gain

Sultan Sütlü✉

Acibadem Mehmet Ali Aydinlar University, Department of Computer Engineering, Istanbul, Türkiye

Abstract

Motivated by the photocatalytic removal of microplastics [1], we study a simple mathematical model for the feedback control of such reactors. The model is a three-dimensional autonomous ODE system with three state variables: the pollutant concentration, the actuator output, and the feedback gain of the actuator. The gain is not a fixed parameter; it changes in time according to an adaptation law, as in adaptive control [2]. The adaptation speed is denoted by κ. The pollutant and the actuator are coupled by a bilinear term, which is the only nonlinear term in the model. We first show that, if the inflow of pollutant is larger than what natural decay can remove at the target concentration, the system has exactly one positive equilibrium point, and we give it explicitly.

We then study the local stability of this equilibrium with the Routh–Hurwitz criterion [3]. The result is a complete description in terms of κ: there is a critical value κ_c, given by an explicit formula, such that the equilibrium is locally asymptotically stable for $\kappa < \kappa_c$ and unstable for $\kappa > \kappa_c$. At $\kappa = \kappa_c$ the Jacobian matrix has a pair of purely imaginary eigenvalues, and this pair crosses the imaginary axis with nonzero speed. Therefore a Hopf bifurcation occurs and periodic solutions appear near the equilibrium [4]. The frequency of these oscillations at the critical value does not depend on κ; it depends only on the parameters of the controlled process. Numerical simulations support the theoretical findings: as κ increases, solutions display first non-oscillatory convergence, then damped oscillations, and eventually sustained periodic behaviour corresponding to a stable limit cycle. These results demonstrate that excessively fast adaptation of the gain renders the control loop itself a source of instability.

Keywords: adaptive control, Hopf bifurcation, Routh–Hurwitz criterion, local stability, photocatalytic reactor, microplastic degradation

References

[1] Hamd, W., Daher, E., Tofa, T.S., & Dutta, J. (2022). Recent advances in photocatalytic removal of microplastics: mechanisms, kinetic degradation, and reactor design. Frontiers in Marine Science, 9, 885614.
[2] Ioannou, P.A., & Sun, J. (2012). Robust Adaptive Control. Dover Publications, Mineola, NY.
[3] Khalil, H.K. (2002). Nonlinear Systems. 3rd ed. Prentice Hall, Upper Saddle River, NJ.
[4] Kuznetsov, Y.A. (2004). Elements of Applied Bifurcation Theory. 3rd ed. Springer, New York.

✉ Corresponding Author Email: *sultan.sutlu@acibadem.edu.tr*

Optimal transport for Empirical Bayes estimation for Wavelet analysis with spatial single cell data

Mehmet Ali Kaygusuz✉

Anadolu University Department of Economics, Eskişehir, Turkey

Abstract

Traditionally, Optimal transport (OT) for single-cell data is a powerful mathematical framework used to compare and align high-dimensional cellular profiles—especially useful for understanding dynamic processes, integrating datasets, and mapping spatial organization. Here's how it works and why it's transformative: On the other hand, Wavelet analysis is a mathematical technique used to analyze signals, data, or time series at different scales or resolutions. Unlike traditional Fourier analysis, which shows what frequencies are present in a signal, in other words, wavelet analysis can show both when and at what scale/frequency certain features occur. The core idea is to break a signal into small wave-like functions called wavelets. These wavelets can be stretched or compressed to examine large-scale trends and fine details. empirical Bayes analysis is a statistical approach that combines ideas from traditional statistics and Bayesian statistics. On the other hand, In standard Bayesian analysis, you specify a prior distribution (your beliefs before seeing the data). In Empirical Bayes, instead of choosing the prior purely from expert knowledge, you estimate the prior from the observed data itself. Suppose you're analyzing spatial single-cell data and want to predict gene expression, cell types, or spatial domains. Fit an Empirical Bayes model. Estimate shared distributions across genes, cells, or regions. Therefore optimal transport for wavaelt analsyis and deep neural networks can be very hepful to improve computational hurdles to calcluate spatial singel cell data. Empirical Bayes: improves estimates through shrinkage and information sharing. Genomics When analyzing expression levels across 20,000 genes with only a few biological replicates per gene, uses Empirical Bayes to stabilize variance estimates across genes. In single-cell biology we examined dimensionality reduction performs better estimation than the singular value decomposition (SVD) under low signal-to-noise (SNR) regime and to perform gene dimensionality reduction that retains inferred spatial single cell data.

Keywords: Optimal transport, Emprical Bayes, estimation Wavelet analysis, Spatial data

References

[1] Johnstone, I. M., & Silverman, B. W. (2005). Empirical Bayes selection of wavelet thresholds.
[2] Seo, K., & Lim, J. (2026). Conformalized Method for Empirical Bayes Normal Mean Inference Problem with Heteroscedastic Variance. *arXiv preprint arXiv:2604.01629*.
[3] Wang, W., & Stephens, M. (2021). Empirical Bayes matrix factorization. *Journal of Machine Learning Research*, *22*(120), 1-40.
[4] Zhao, Z., & Sun, W. (2025). A Conformalized Empirical Bayes Method for Multiple Testing with Side Information. *arXiv preprint arXiv:2502.19667*.

✉ Corresponding Author Email: *makaygusuz1988@gmail.com*

Bifurcation, Chaos, and Control in a Discretized Fractional-Order Ecological Model

Neriman Kartal✉

Nevşehir Hacı Bektaş Veli University, Department of Mathematics and Science Education, Nevşehir, Turkey

Abstract

In this study, a modified Richards growth model with varying carrying capacity and the Allee effect is considered. Since complex dynamical behaviors in continuous-time systems generally arise only in higher-dimensional settings, one and two-dimensional continuous models are limited in their ability to exhibit such phenomena. To overcome this limitation and capture the rich dynamical patterns observed in ecological systems, a discretization procedure based on piecewise constant arguments is applied to the continuous-time Richards model, yielding a two-dimensional difference equation system.

The positive equilibrium points of the resulting model are determined, and their local stability properties are investigated. The analysis reveals the occurrence of both Flip and Neimark--Sacker bifurcations as the system parameters pass through critical values. Furthermore, the emergence of chaotic dynamics following these bifurcations is confirmed through the computation of maximum Lyapunov exponents. Moreover, the chaotic windows persist over continuous parameter intervals, indicating that the observed complex dynamics are robust under small parameter perturbations. To suppress chaotic oscillations, two control strategies, namely state-feedback control and hybrid control, are implemented. Numerical simulations show that both control approaches successfully eliminate chaos, stabilize the desired equilibrium state, and significantly enlarge the corresponding stability regions. Numerical bifurcation diagrams, phase portraits, and maximum Lyapunov exponents confirm the occurrence of transitions among stable equilibria, periodic solutions, quasi-periodic motions, and chaotic regimes. The results indicate that variations in environmental carrying capacity and Allee threshold levels may substantially alter the long-term persistence of the population. The findings further suggest that memory effects play a significant role in shaping population responses to environmental changes.

Keywords: Stability, bifurcation, chaos

References

[1] Rana, S.M.S., & Uddin, M.J. (2026). Incorporating memory effects in population ecology using fractional derivatives: Stability perspectives, bifurcations, and chaos control. Complexity, 2026(1).
[2] Zhao, M., Xuan, Z., & Li, C. (2016). Dynamics of a discrete-time predator-prey system. Advances in Difference Equations, 2016(1).
[3] Sandri, M. (1996). Numerical calculation of Lyapunov exponents. The Mathematica Journal, 6(3), 78–84.
[4] Singh, A., & Deolia, P. (2020). Dynamical analysis and chaos control in discrete-time prey-predator model. Communications in Nonlinear Science and Numerical Simulation, 90, 105313.
[5] Zhang, J., & Tang, W. (2012). Optimal control for a class of chaotic systems. Journal of Applied Mathematics, 2012(1).
[6] Song, N. (2023). Bifurcation and chaos of a nonlinear discrete-time predator-prey model involving the nonlinear Allee effect. Discrete Dynamics in Nature and Society, 2023, 1–32.

✉ Corresponding Author Email: nerimangok@nevsehir.edu.tr

Optimal transport trajectories for deep cardiovascular spatial single cell data

Mehmet Ali Kaygusuz[1], Melih Ağraz[2,3] Gaurav Choudhary [3]

[1] Anadolu University, Department of Economics, Eskisehir, Turkey
[2] Giresun University, Giresun Turkey
[3] Brown University, Albert Medicine School, USA

Abstract

For single-cell data, optimal transport (OT) is used to match or align cells, cell populations, or distributions of cells across different conditions, time points, or experiments. More specifically, the key idea is that each cell is represented as a point in a high-dimensional space (e.g., gene expression), and OT finds the most plausible way to "move" one population of cells to another. OT particularly well suited to single-cell sequencing, where experiments provide snapshots of populations rather than continuous observations of individual cells. It enables researchers to infer how cell populations change over time or under different conditions despite not tracking the same physical cells. On the other hand, optimal transport (OT) extends the standard idea by considering both gene expression and the physical locations of cells. The goal is not only to match similar cells, but also to preserve the spatial organization of the tissue. It involves using single-cell sequencing technologies to study how individual cells within the heart behave, mutate, and communicate during the progression of cardiovascular diseases. Even though [1] have used kantorovich relaxation, entropy regularization and sinkhorn optimization algorithm as a part of optimal transport for spatial single cell cardiovascular data, to our best knowledge there is no study yet about similar optimization algorithm for vascular stromal and mesothelial cells thorough immune cells cardiac and hemostasis using with deep variational autoencoder [3]. Therefore, standard single-cell methods (like scRNA-seq) tell you what cells are present in the heart, they require breaking the tissue apart, which destroys the "map." Spatial transcriptomics and spatial proteomics allow researchers to see where those cells are located and who their "neighbors" are within the intact heart tissue. More specifically, when we use kantorovich relaxation and sinkhorn optimization algorithm for spatial cardiovascular single cell data, a strict one-to-one mapping might be biologically unrealistic due to one spatial spot can contain multiple cell types and one cell state can occur at many spatial locations scRNA-seq. From different perspective, spatial data have different sampling distributions cell numbers in the two datasets usually aren't equal. Consequently, Kantorovich OT provides the mass of one source cell/state to be split across multiple target locations, rather than requiring a deterministic one-to-one mapping. This is how we use optimal transport has been used for scRNA-seq spatial cardiovascular data.

Keywords: Cardiovascular disease, spatial data, multiple testing

References

[1] Klein, D., Palla, G., Lange, M., Klein, M., Piran, Z., Gander, M., ... & Theis, F. J. (2025). Mapping cells through time and space with moscot. *Nature*, *638*(8052), 1065-1075.
[2] Maron, B. A., Brittain, E. L., Hess, E., Waldo, S. W., Barón, A. E., Huang, S., ... & Choudhary, G. (2020). Pulmonary vascular resistance and clinical outcomes in patients with pulmonary hypertension: a retrospective cohort study. *The Lancet Respiratory Medicine*, *8*(9), 873-884.
[3] Litviňuková, M., Talavera-López, C., Maatz, H., Reichart, D., Worth, C. L., Lindberg, E. L., & Teichmann, S. A. (2020). Cells of the adult human heart. *Nature*, *588*(7838), 466-472.

✉ Corresponding Author Email: Gaurav_Choudhary@brown.edu

A Statistical and Mathematical Approach for Estimating Time-Varying Parameters in a SIRD Model of COVID-19 Outbreak

Gökçe Özaltun Şimşek, Gözde Yazgı Tütüncü, Sevin Gümgüm✉

İzmir University of Economics, Mathematics Department, İzmir, Türkiye

Abstract

In this study, we propose a dual statistical and mathematical approach to estimate the time-varying parameters related to the SIRD model of COVID-19 outbreak. We analyze the data set provided by the Johns Hopkins University (JHU) COVID-19 time series. This data set includes cumulative daily records of confirmed cases, recoveries, and deaths. We start by obtaining our initial parameter estimates using discrete difference equations. To filter out the noise from the reports of fluctuations, we use a statistical smoothing technique that allows us to simulate the true trends in the dynamics of the pandemic. Afterwards, we fit these time-dependent parameters using a least-square approach to simulate the long-term behaviors of all populations. We present a comparison of the numerical results obtained by the estimation of the model using constant and time-variable parameters with the real-world data for a 150-day period in Türkiye. The results demonstrate that using constant parameters is not effective in simulating the dynamics of the system, and using time-variable parameters instead results in more accurate solutions and capture the epidemic dynamics better, significantly enhancing the realism of the SIRD model. Ultimately, our approach offers a powerful way to better understand the ever-changing nature of infectious disease outbreaks.

Keywords: SIRD Model, Parameter Estimation, Statistical Smoothing, Least Square Fitting

References

[1] Bentout, S., Chekroun, A., & Kuniya, T. (2020) Parameter estimation and prediction for coronavirus disease outbreak 2019 (COVID-19) in Algeria, AIMS Public Health, 7(2), 306-318.

[2] Mehra, A.H.A., Shafieirad, M., Abbasi, Z., & Zamani, I. (2020) Parameter estimation and prediction of COVID-19 epidemic turning point and ending time of a case study on SIR/SQAIR epidemic models, Computational and Mathematical Methods in Medicine, Article ID 1465923, 13 pages.

[3] Otunuga, O.M. (2021). Estimation of epidemiological parameters for COVID-19 cases using a stochastic SEIRS epidemic model with vital dynamics, Journal of Mathematical Analysis and Applications, 499(1) 125018.

✉ Corresponding Author Email: *sevin.gumgum@ieu.edu.tr*

A Diagonal-scaled Conjugate Gradient Algorithm for Large-Scale Unconstrained Optimization with Application to Regularization-Free Image Denoising

Sulaiman Mohammed Ibrahim[1]✉, Hassan Mohammed[2],

[1] *Department of Basic and Applied Sciences, College of Applied and Health Sciences, A'Sharqiyah University, 400 Ibra, Oman*
[2] *Nonlinear Dynamics & Mathematical Application Center, Department of Mathematics, Kyungpook National University, Daegu 41566, Republic of Korea*

Abstract

Nonlinear conjugate gradient (CG) methods are widely used for large-scale unconstrained optimization due to their low memory requirements and simplicity. Despite their efficiency and robustness, studies showed that numerous classical and recent CG algorithms suffer from slow convergence on ill-conditioned problems and often fail to guarantee sufficient descent without restrictive line search conditions. In response, this paper proposes a diagonal-scaled conjugate gradient (DSCG) algorithm that integrates the new CG coefficient into a diagonal Hessian approximation scheme. We prove that the proposed direction satisfies sufficient descent, Dai-Liao-type conjugacy, and trust region properties independent of line search. Global convergence and iterative complexity are established under standard line search conditions. Further, the algorithm is applied to regularization-free image denoising, where implicit regularization emerges from spectral filtering and early stopping. Numerical experiments on a set of benchmark unconstrained optimization problems (dimensions up to 500,000) show that the proposed method reduces iteration counts by 10 - 40% and CPU time by 15 - 50% existing algorithms. On image restoration, DSCG algorithm achieves PSNR values comparable to or better than existing methods while requiring no regularization parameter tuning. The results confirm that DSCG is a robust, efficient, and scalable algorithm for unconstrained optimization and regularization-free image denoising.

Keywords: Conjugate gradient, Optimization problem, sufficient Descent, Convergence analysis, Image restoration,

Acknowledgements

The authors are grateful to A'Sharqiyah University for their financial support.

References

[1] Mohammad, H., Ibrahim, S. M., Choi, H., & Yunus, R. B. (2025). A diagonal Hestenes-Stiefel conjugate gradient algorithm with iterative complexity analysis and its application in robotic model. *Operations Research Perspectives*, 100375.
[2] Babaie-Kafaki, S. (2023). A survey on the Dai–Liao family of nonlinear conjugate gradient methods. *RAIRO-Operations Research*, *57*(1), 43-58.
[3] Andrei, N. (2020). *Nonlinear conjugate gradient methods for unconstrained optimization*. Berlin, Heidelberg: Springer International Publishing.
[4] Concus, P., Golub, G. H., & Meurant, G. (1985). Block preconditioning for the conjugate gradient method. *SIAM Journal on Scientific and Statistical Computing*, *6*(1), 220-252.

✉ Corresponding Author Email: sulaiman.ibrahime@asu.edu.om

A Fuzzy-Evolutionary Game Theory Framework for Patent Portfolio Management in Technology Transfer Offices

Samet Kürşat Başol[✉1,2], Yunus Eroğlu[2], Türkay Dereli[3], Alptekin Durmuşoğlu[4]

[1] *Gaziantep University TargeT Technology Transfer Office Inc., Gaziantep, Türkiye*
[2] *Gaziantep University, Industrial Engineering Department, Gaziantep, Türkiye*
[3] *TOBB University of Economics and Technology, Industrial Engineering Department, Ankara, Türkiye*
[4] *Samsun University, Industrial Engineering Department, Samsun, Türkiye*

Abstract

Low technology readiness level patents form a significant part of the technology transfer portfolio of a university, and they provide a considerable level of uncertainty for the technology transfer offices (TTO's) in commercializing their output. Literature has been written on the process in two main streams: approaches of assessment on match between technological maturity and market demand through static thresholds and studies of evolutionary game theory (EGT) in modeling University-Industry interactions as behavior games in Government-University-Industry triad. This study combines the two streams by building a fuzzy logic-based evolutionary game theory model with the TTO playing as one agent in the managing of low technology readiness level patent portfolio.

A fuzzy inference system is used within a University-TTO-Firm interaction system to generate probabilities of success, investment intensity requirements as output based on inputs of technological maturity level of patent, demand side maturity level of patent, absorptive capacity of firm, and experience level of TTO. Treating these outputs as fuzzy variables rather than crisp values, fixed parameters of payoffs have been treated as fuzzy values, so a single equilibrium point is transformed into an equilibrium region and a third, interim strategy-partial commitment-can exist in equilibrium, which cannot be achieved with crisp parameters and binary strategies.

This study contributes in three ways. First, the TTO is treated as a player with its own utility function rather than as a passive intermediary. Second, fuzzy inference is used to translate the mismatch between technological readiness and market demand into the payoff structure, capturing a source of uncertainty that earlier models leave out. Third, the resulting partial-commitment strategy is incorporated into the equilibrium analysis, an option that binary-strategy formulations cannot represent.

Keywords: Technology Transfer Office, evolutionary game theory, fuzzy inference system,

References

[1] Zhong, Q., Cui, H., Yang, M., & Ling, C. (2025). Research on Stochastic Evolution Game of Green Technology Innovation Alliance of Government, Industry, University, and Research with Fuzzy Income. Sustainability, 17(5), 2294.

[2] Ahemad, F., Gupta, P., Mehlawat, M. K., Deveci, M., & Jin, L. (2025). A multi-criteria decision-making approach using bipolar fuzzy numbers for optimizing two-sided matching in technology transfer decisions. Applied Soft Computing, 113633.

[3] Tibay, E., Quiñones, R., Quiñones, H., Selerio, E., Evangelista, S. S., Aro, J. L., ... & Ocampo, L. (2022). Optimal planning of university technology transfer measures with FDANP-F-FlowSort and an extended multiobjective PROMETHEE V. IEEE Access, 10, 56629-56651.

[4] Cucino, V., Del Sarto, N., Di Minin, A., & Piccaluga, A. (2021). Empowered or engaged employees? A fuzzy set analysis on knowledge transfer professionals. Journal of Knowledge Management, 25(5), 1081-1104.

✉ Corresponding Author Email: *sametkursatbasol@gmail.com*

A Theoretically Grounded Attention-DenseNet with Dual Stochastic Activations for Mammographic Cancer Classification on INbreast and MIAS

Khaddouj Taifi[1], Yassine Sabbar[2], Necati Ozdemir[3]

[1]*IPDAC Team, Department of Informatics, FST Errachidia, Moulay Ismail University of Meknes, P.O. Box509, 52000, Boutalamine, Morocco*
[2]*IMIA Laboratory, T-IDMS, Department of Mathematics, FST Errachidia, Moulay Ismail University of Meknes, P.O. Box 509, 52000, Boutalamine, Errachidia, Morocco*
[3]*Department of Mathematics, Balıkesir University, Cagis Campus, Balikesir, 10145, Turkiye*

Abstract

This work proposes AttenDense, an enhanced DenseNet framework for mammographic breast cancer classification. The architecture integrates global CBAM attention, Squeeze-and-Excitation channel recalibration, stochastic Swish activation, and GELU-based nonlinear transformation to improve feature discrimination and model generalization. Experiments using DenseNet121 and DenseNet201 backbones on the INbreast and MIAS datasets achieve accuracies of 99.9% and 99%, respectively, demonstrating the effectiveness of the proposed architecture against baseline and competing approaches.

Keywords: Breast cancer diagnosis; Mammography; DenseNet; Attention mechanisms; CBAM; Squeeze-and-Excitation; Stochastic Swish; GELU activation; Deep learning.

References

[1] Taifi, K., Sabbar, Y., Ardah, H., & Abdel-Aty, A. H. (2025). Enhanced dl-based breast cancer diagnosis and classification using modified densenet-121, densenet-201, and mobilenetv2: Optimized architectures and refined activation functions. IEEE Access.

[2] Shahid, M. S., & Imran, A. (2025). Breast cancer detection using deep learning techniques: challenges and future directions. *Multimedia Tools and Applications*, *84*(6), 3257-3304.

[3] Lawal, M. K. B., Almousa, M., Ibrahim, A. U., Pwavodi, P. C., Usman, A. G., & Aloraini, B. (2025). Artificial intelligent-powered detection of breast cancer. *Journal of Radiation Research and Applied Sciences*, *18*(2), 101422.

✉ Corresponding Author Email: k.taifi@umi.ac.ma, y.sabbar@umi.ac.ma

Structural Analysis of a Dynamically Constrained Mobile Facility Location Problem on Tree Networks

Nazlı Karataş Aygün✉, Haluk Eliş

Yaşar University, Industrial Engineering Department, Izmir, Türkiye

Abstract

Olive oil quality is strongly affected by the delay between harvesting and processing. This motivates the use of mobile olive mills that can be relocated during the harvesting season in order to remain close to the olive groves that are currently active [1]. The overall planning problem for mobile olive mills combines harvesting schedules, processing schedules, and relocation decisions. The interaction among these decisions gives rise to a challenging integrated optimization problem. We focus on the relocation problem that arises once a feasible harvesting and processing schedule has been fixed. The mill may be positioned at any point on the underlying continuous tree network.

In many agricultural regions, transportation access is organized around road networks with limited alternative routes, and tree networks provide a natural abstraction of such settings. At the same time, the unique-path property of trees makes it possible to isolate the geometric effect of mobility without the additional complications caused by cycles.

The main operational feature of the problem is that the mill cannot be relocated while processing is ongoing. This leads to time-dependent locations that are driven by the harvesting and processing schedule. For a fixed feasible schedule, this constraint decomposes the planning horizon into maximal time blocks during which the mill must remain at a constant location. The fixed-schedule relocation subproblem is analyzed by exploiting the geometric structure of the tree. The feasible location sets are decomposed into maximal simple segments, and the local behavior on each segment is represented through a one-dimensional location model. This segment-based viewpoint provides the foundation for studying the structural properties of the continuous relocation problem [2].

Keywords: Mobile facility location; mobile olive mill; tree networks; scheduling-location integration; continuous network location

References

[1] Urra-Calfuñir, B. A., Monardes-Concha, C. A., & Miranda-González, P. A. (2024). Agri-food supply chain optimization through a decentralized production process in the olive oil industry. Computers & Industrial Engineering, 192, 110185. https://doi.org/10.1016/j.cie.2024.110185

[2] [2] Hooker, J. N., Garfinkel, R. S., & Chen, C. K. (1991). Finite dominating sets for network location problems. Operations Research, 39(1), 100–118. https://doi.org/10.1287/opre.39.1.100

✉ Corresponding Author Email: *nazli.aygun@yasar.edu.tr*

A Multi-Objective Decision Support Model for Electric Bus Configuration Selection: A Pareto-Optimality Approach

Ali Yiğit Sabaner✉, Ece Nur Polat, Ramazan Yaman

Balikesir University, Department of Industrial Engineering, Balikesir, Türkiye

Abstract

The electrification of public transportation has become a system-level design problem shaped by route-dependent energy use, operational requirements, and high investment costs. For purpose-built electric buses on fixed urban routes, configuration decisions should be evaluated jointly, since battery size, technology, traction power, auxiliary loads, charging limits, and economic outcomes interact during daily service. This study proposes a multi-objective decision support model for selecting an electric bus configuration that satisfies route-specific requirements. Battery capacity, battery technology, nominal motor power, HVAC load, and powertrain ratio are treated as integrated decision variables. Three conflicting objectives are considered: minimizing Total Cost of Ownership, including investment and energy costs; maximizing operational range; and maximizing operational reliability through route-completion feasibility and reserve-energy capability. Consistent with studies on battery sizing and charging strategy optimization [1], uncertain route-dependent energy demand [2], integrated powertrain optimization [3], and Pareto-based bus scheduling and charging frameworks [4], the model includes slope, climate, regenerative braking efficiency, and charging infrastructure limits as constraints. The model is solved using a Pareto-optimality approach, generating non-dominated configurations rather than a single aggregated solution. Thus, decision-makers can assess trade-offs among cost efficiency, technical performance, and operational robustness under the same route scenario. The study contributes a configuration-selection framework linking electric bus design parameters with feasibility indicators and shows that route-specific planning can support balanced vehicle-parameter selection under economic and operational constraints.

Keywords: Electric bus configuration, multi-objective optimization, Pareto optimality, Total Cost of Ownership, decision support system

References

[1] Basma, H., Mansour, C., Haddad, M., Nemer, M., & Stabat, P. (2023). A novel method for co-optimizing battery sizing and charging strategy of battery electric bus fleets: An application to the city of Paris. *Energy, 285*, 129459. https://doi.org/10.1016/j.energy.2023.129459

[2] Davazdah Emami, B., Zhang, Y., Khani, A., & Song, Y. (2025). Towards an efficient electric bus system: Multi-phase optimization model for incremental electrification of bus network with uncertain energy consumption. *Transportation Research Part C: Emerging Technologies, 173*, 105011. https://doi.org/10.1016/j.trc.2025.105011

[3] Kwon, K., Seo, M., & Min, S. (2020). Multi-objective optimization of powertrain components for electric vehicles using a two-stage analysis model. *International Journal of Automotive Technology, 21*(6), 1495-1505. https://doi.org/10.1007/s12239-020-0141-5

[4] Dabčević, Z., Škugor, B., & Deur, J. (2026). MILP-based Pareto optimization of electric bus scheduling and charging management. *Energies, 19*(3), 867. https://doi.org/10.3390/en19030867

✉ Corresponding Author Email: *aliyigit.sabaner@balikesir.edu.tr*

Convergence Theorems for the McShane Integral in Locally Convex Riesz Spaces

Ismet Temaj, Esma Canhasi Kasemi✉

University of Prizren "Ukshin Hoti", Faculty of Education, Prizren, Kosovo

Abstract

In this paper, we establish new convergence theorems for the McShane integral of functions taking values in locally convex Riesz spaces, that is, topological vector lattices whose topology is generated by families of monotone continuous seminorms. By employing regulator methods together with (0)-convergence and (D)-convergence, we extend classical convergence principles to a broader order-topological setting. Our approach is based on a regulator-mixing argument that allows several seminorm estimates to be combined into a single control mechanism, which is essential in spaces where ordinary norm-based arguments are not available. The main results of the paper include a uniform convergence theorem and a conditional monotone convergence theorem for McShane integrable functions. In the uniform convergence result, we show that a uniformly Cauchy sequence of McShane integrable functions admits a McShane integrable limit and that the corresponding sequence of integrals converges in the topology generated by the family of monotone seminorms. In the monotone convergence result, we prove that, under an additional assumption on the existence of the limit of the integrals, pointwise monotone convergence also yields convergence of the integrals. These results generalize earlier convergence theorems from Banach spaces and classical Riesz spaces to the more flexible framework of locally convex Riesz spaces [1–3]. The theory is illustrated by examples showing that the convergence results remain valid both in familiar function spaces and in non-metrizable locally convex Riesz spaces. The results demonstrate that regulator techniques provide an effective substitute for norm-based domination arguments and offer a natural tool for studying McShane integration in ordered topological vector spaces [4, 5].

Keywords: McShane integral, locally convex Riesz space, regulators, (0)-convergence, (D)-convergence, monotone convergence

References

[1] Bartle, R. G. (2001). A modern theory of integration. American Mathematical Society.
[2] Gordon, R. A. (1990). The McShane integral of Banach-valued functions. Illinois Journal of Mathematics, 34, 557–567.
[3] Temaj, I., & Canhasi-Kasemi, E. (2027). Convergence theorems for the McShane integral in locally convex Riesz spaces. Journal of Contemporary Applied Mathematics, 17(1), 31–53. https://doi.org/10.62476/jcam171.3
[4] Luxemburg, W. A. J., & Zaanen, A. C. (1971). Riesz spaces I. North-Holland.
[5] Schaefer, H. H., & Wolff, M. P. (1999). Topological vector spaces (2nd ed.). Springer.

✉ Corresponding Author Email: *esma.canhasi.kasemi@uni-prizren.com*

Dynamic Programming using Average-Value-at-Risk Criteria

Kerem Ugurlu

Nazarbayev University, Mathematics Department, Astana, Kazakhstan

Abstract

We investigate dynamic programming equations on Average-Value-at-Risk (AVaR) using machine learning techniques and demonstrate several simulations. The dynamic programming equation on AVaR is specifically using a so-called "state aggregation technique" that makes use of the sufficient statistic of the optimization problem. Via state aggregation, we present the "Markovian" framework and demonstrate several implementations using ML techniques. The risk averseness level alpha on the model is also investigated via several simulations.

Keywords: Average-Value-at-Risk, Robust Stochastic Control, Dynamic Programming

Corresponding Author Email: *keremugurlu@gmail.com*

Integrating exclusion constraints into the Traveling Salesman Problem: An Application to Formula 1 Calendar Design

Anett Rácz✉, Lajos Tóth

University of Debrecen,Faculty of Informatics, Department of Applied Mathematics and Probability Theory, Debrecen, Hungary

Abstract

The Traveling Salesman Problem (TSP) is a foundational optimization model with broad applications in logistics, manufacturing, and scheduling. This paper extends the classical Miller-Tucker-Zemlin TSP formulation [1] with positional exclusion constraints, formulated as either-or logical conditions using auxiliary binary variables, to capture real-world scheduling restrictions such as holidays or competing events.

The model is illustrated through the design of the 2026 Formula 1 race calendar, where the optimized schedule is compared, in terms of total distance and runtime, to both the official calendar and the unconstrained shortest route. The optimized solution achieves a substantial distance reduction relative to the official calendar.

We further examine how an increasing number of exclusion constraints affects solver runtime, observing an approximately linear growth. The model was implemented in Python using Gurobi [2] and Folium [3] for visualization, and generalizes to other domains with position-based restrictions.

Keywords: Traveling Salesman Problem, Integer Programing, Mixed-Integer Linear Programming

References

[1] Miller, C.E., Tucker, A. W., & Zemlin, R. A. (1960). Integer formulation of travelling-salesman problems. Journal of the Association for Computing Machinery, 7(4), 326-329.

[2] Gurobi Optimization, LLC. (2024). Gurobi Optimizer (Version 11.0.0) [Computer software]. https://www.gurobi.com

[3] Folium Contributors. (2024). Folium (Version 0.17.0) [Computer software]. https://python-visualization.github.io/folium/

✉ Corresponding Author Email: *anett.racz@inf.unideb.hu*

Physics-Informed Neural Network Approximation of Nonlocal Transport Models for Engineering Density-Flow Simulation

Vladyslav Cherkashyn✉, Artem Naumovets

V.N. Karazin Kharkiv National University, Kharkiv, Ukraine

Abstract

Reliable simulation of transport processes with nonlocal interactions is important for engineering tasks in which the state of a system depends not only on local values but also on averaged information from a surrounding region. This work presents a physics-informed neural network (PINN) formulation for a one-dimensional conservation-law model of interacting density fields. The model represents two populations by continuous densities and defines their fluxes through advection, diffusion, and convolution-based interaction terms describing avoidance of high-density zones [1].

The aim is to evaluate whether a neural approximation can reproduce the principal transport mechanisms of this system while preserving physical constraints. The PINN takes space and time as inputs and returns both density components. Its loss function combines residuals of the governing partial differential equations with initial, boundary, and consistency constraints. Derivatives are obtained by automatic differentiation, following the general PINN framework [2]. The nonlocal part is evaluated as a precomputed discrete convolution operator, which keeps the interaction term differentiable and avoids unstable direct integration during training.

Numerical experiments are performed for two groups with different preferred velocities. The computed solution shows moving density fronts, interaction zones, and gradual interpenetration of the two populations without artificial discontinuities. Verification is carried out by comparison with a finite-difference scheme based on a Rusanov-type numerical flux, commonly used for conservation laws [3]. The comparison confirms that the neural solution reproduces the qualitative structure of the reference calculation and remains stable under variations of velocity, diffusion, and interaction radius. These results support the validity of PINNs for nonlocal transport modelling and indicate their potential for higher-dimensional engineering problems, where finite-difference methods can become limited by available computational resources.

Keywords: physics-informed neural networks, nonlocal transport models, conservation laws, density-flow simulation, finite-difference verification, engineering modelling.

References

[1] Colombo, R.M., & Lécureux-Mercier, M. (2012). Nonlocal crowd dynamics models for several populations. Acta Mathematica Scientia, 32(1), 177–196. https://doi.org/10.1016/S0252-9602(12)60011-3

[2] Raissi, M., Perdikaris, P., & Karniadakis, G.E. (2019). Physics-informed neural networks: A deep learning framework for solving forward and inverse problems involving nonlinear partial differential equations. Journal of Computational Physics, 378, 686–707. https://doi.org/10.1016/j.jcp.2018.10.045

[3] Toro, E.F., Saggiorato, B., Tokareva, S., & Hidalgo, A. (2020). Low-dissipation centred schemes for hyperbolic equations in conservative and non-conservative form. Journal of Computational Physics, 416, 109545. https://doi.org/10.1016/j.jcp.2020.109545

✉ Corresponding Author Email: *dashevskiy.cherkashin.vladislav@gmail.com*

Qualitative Analysis and Numerical Simulation of a Caputo Fractional-Order Lyme Disease Model with Wildlife-Maintained Tick Infection Pressure

Waleed Adel[1,2]✉, Haci Mehmet Baskonus[3,4]

[1] *Nanoelectronics Integrated Systems Center, Nile University, Giza, 12588, Egypt.*
[2] *Department of Mathematics and Engineering Physics, Faculty of Engineering, Mansoura University, Mansoura 35516, Egypt*
[3]*Department of Mathematics and Science Education, Faculty of Education, Harran University, Sanliurfa, Turkey,*
[4]*Scientific Research Department, Azerbaijan University of Architecture and Construction, Baku, Azerbaijan*

Abstract

Lyme disease, caused by *Borrelia burgdorferi* and transmitted through infected *Ixodes* ticks, represents a major public-health burden, with approximately 476,000 individuals diagnosed and treated annually in the United States [1]. Its transmission involves complex interactions among wildlife reservoirs, tick populations, and humans. Classical integer-order models do not fully represent the hereditary and non-local effects associated with these processes, whereas fractional differential equations provide an appropriate framework for incorporating epidemiological memory [2]. This study develops a dimensionally consistent Caputo fractional-order model for Lyme disease transmission under persistent wildlife-maintained tick infection pressure. Extending previous mathematical models of tick-borne disease transmission [4], the system comprises seven compartments: susceptible, exposed, infected, treated, and recovered humans, together with susceptible and infected ticks. Humans are considered incidental dead-end hosts and therefore do not contribute to tick infection. Instead, susceptible ticks acquire infection through a constant background force representing exposure to competent wildlife reservoirs. The model's fundamental properties, including positivity, boundedness, population balance, and equilibrium behavior, are examined. Numerical solutions are obtained using the Adams–Bashforth–Moulton predictor-corrector method for Caputo fractional equations [3] and validated at the integer-order limit, ($\alpha = 1$), against MATLAB's ode45 solver. Simulations for different fractional orders under low, moderate, and high exposure scenarios show that the memory parameter strongly affects transient disease dynamics. Lower values of (α) delay susceptible depletion and recovery accumulation while maintaining higher residual levels of exposed, infected, and treated individuals. The cumulative active and clinical disease burdens also exhibit non-monotonic dependence on (α), demonstrating that epidemiological memory influences infection timing, duration, and overall burden.

Keywords: Lyme disease; Caputo fractional derivative; Adams's predictor-corrector method; wildlife reservoir; infected ticks; human exposure index; memory effects; forced endemic equilibrium.

References

[1] Centers for Disease Control and Prevention. (2021). Lyme disease data and statistics. U.S. Department of Health & Human Services. https://www.cdc.gov/lyme/datasurveillance/index.html
[2] Kilbas, A. A., Srivastava, H. M., & Trujillo, J. J. (2006). Theory and applications of fractional differential equations. Elsevier.
[3] Diethelm, K., Ford, N. J., & Freed, A. D. (2002). A predictor-corrector approach for the numerical solution of fractional differential equations. Nonlinear Dynamics, 29, 3-22.
[4] Elsonbaty, A., Teklu, S. W., Ramaswamy, R., Padmaja, S., & Adel, W. (2026). A mathematical model for the co-transmission dynamics of Lyme disease and babesiosis with awareness-driven behavioral responses. The European Physical Journal Plus, 141(4), 410.

✉*Corresponding author: wauof@nu.edu.eg*

Explainable Fractional-Order Intelligent Predictive Control Framework for Nonlinear Cyber-Physical Systems under Uncertainty

Oluwaseun Olumide Okundalaye[1]✉, Necati Ozdemir[2], Mario Raso[3]

[1]*Department of Mathematical Sciences, Adekunle Ajasin University, Akungba-Akoko, Nigeria*
[2]*Department of Mathematics, Balıkesir University, Turkey*
[3]*Department of Computer Science, Sapienza University of Rome, Italy*

Abstract

In modern cyber-physical systems, including smart grid and biomedical systems, severe nonlinearities, uncertainties, and safety constraints exist. Traditional control methods are not adaptive, and black-box AI is not interpretable and does not have formal stability guarantees. To do this, this paper introduces the Explainable Fractional-Order Intelligent Predictive Control (EFIPC) framework, which unifies six complementary pillars: (i) fractional-order dynamics (to capture long-range memory and hereditary effects); (ii) model predictive control (receding-horizon optimization with learned predictors); (iii) fractional reinforcement learning (online adaptation of controller parameters and fractional orders using memory-aware gradient descent); (iv) metaheuristic hyperparameter tuning (PSO/GA); (v) explainable AI (SHAP, rule extraction, trust scores, counterfactuals); and (vi) Lyapunov-based stability guarantees [1-3]. The EFIPC framework is validated in two application fields: smart grid energy management (power data from the smart grid in Tetuan City) and biomedical glucose-insulin regulation. Experimental results show that EFIPC outperforms classical MPC and fractional-order MPC without RL, and that the RMSE of the RMG is reduced to 22.4 mg/dL while maintaining 86.3% time-in-range for glucose regulation; moreover, it provides real-time, human-understandable explanations and formal closed-loop stability. The EFIPC framework provides a way towards safe, adaptive, transparent, and high-performance control of next-generation autonomous systems.

Keywords: Fractional-order control, model predictive control (MPC), reinforcement learning, explainable artificial intelligence (XAI), Lyapunov stability

References

[1] Ma, Z., Liu, Z., & Huang, P. (2020). Fractional-order control for uncertain teleoperated cyber-physical system with actuator fault. *IEEE/ASME Transactions on Mechatronics*, *26*(5), 2472-2482.
[2] Lu, K. D., Zhou, L., & Wu, Z. G. (2025). Evolutionary fractional-order extended Kalman filter of cyber-physical power systems. *IEEE Transactions on Cybernetics*, *55*(3), 1395-1408.
[3] Okundalaye, O. O., Ozdemir, N., Akinsunmade, A. E., Onuoha, O. A., & Raso, M. (2026). Automated classification of pediatric acute lymphoblastic leukemia: A ResNet-50 deep learning approach. *An International Journal of Optimization and Control: Theories & Applications*, 025340145.

✉*Corresponding Author Email: okundalaye.oluwaseun@aaua.edu.ng*

Optimization in Machine Learning: Training Models Through Loss Function Minimization

Oluwaseun Olumide Okundalaye[1]✉, Necati Ozdemir[2], Ebiwonjumi Ayooluwade[3]

[1,3]*Department of Mathematical Sciences, Adekunle Ajasin University, Akungba-Akoko, Nigeria*
[2]*Department of Mathematics, Balıkesir University, Turkey*

Abstract

Optimization is an essential part of machine learning and AI, as the process by which models learn from data. The main goal of model training is to set the optimal parameters that minimize a given loss function that measures the difference between the model outputs and the target values. The model gradually becomes better at predicting and generalizing with each iteration as this loss is reduced. For navigating through the complex parameter space, several algorithms have been developed, such as Gradient Descent (GD), Stochastic Gradient Descent (SGD), Momentum-based methods, Adaptive Moment Estimation (Adam), RMSProp, and more advanced methods. These algorithms are iterative and aim to converge towards local or global optima by using information from the gradients of the loss function. The optimization process can dramatically impact model performance, training time, stability, and robustness [1-4]. The problems of non-convex objective functions, saddle points, vanishing and exploding gradients, and complexity, however, still continue to spur further research in optimization theory and practice. This research work gives an overview of various optimization methods employed in machine learning, focusing on their theoretical background, implementation, and application for minimizing loss functions. Our comparison study reveals the importance of the convergence speed and stability properties, providing practical guidelines to choose between the different optimizers in various application fields.

Keywords: Optimization, Machine Learning, Loss Function, Gradient Descent, Stochastic Gradient Descent, Adam Optimizer, Neural Networks, Model Training, Convergence Analysis

References

[1] Karthick, K. (2024). Comprehensive overview of optimization techniques in machine learning training. Control Systems and Optimization Letters, 2(1), 23-27.

[2] Abolghasemi, M., Abbasi, B., Babaei, T., & HosseiniFard, Z. (2021). How to effectively use machine learning models to predict the solutions for optimization problems: lessons from loss function. *arXiv preprint arXiv:2105.06618*.

[3] Okundalaye, O. O., Özdemir, N., & Awonusika, R. O. (2026). Early breast cancer prediction using optimized machine learning and tumor-immune modeling. *Journal of Computational and Applied Mathematics*, *473*, 116875.

[4] Okundalaye, O. O., Özdemir, N., & Evirgen, F. (2024, April). Leveraging machine learning for early and accurate anaemia diagnosis: a comparative study of classification algorithms. In *International Conference on Mathematical Modelling, Applied Analysis and Computation* (pp. 42-52). Cham: Springer Nature Switzerland.

✉Corresponding Author Email: okundalaye.oluwaseun@aaua.edu.ng

Comparative Evaluation of Clustering Algorithms for Customer Complaint-Based Failure Analysis in the HVAC Industry

Elif Ünaldı [1]✉, Leyla Demir [2]

[1] *İzmir Bakırçay University, Graduate School, Department of Industrial Engineering, İzmir, Türkiye*
[2] *İzmir Bakırçay University, Faculty of Engineering and Architecture, Department of Industrial Engineering İzmir, Türkiye*

Abstract

Customer complaints constitute one of the most important sources of information for quality improvement, as they directly reflect product and service performance from the customer perspective. Systematic analysis of complaint records enables organizations to identify recurring failure patterns, investigate their root causes, and develop preventive actions to reduce future occurrences. In the HVAC industry, where product reliability and after-sales service quality are critical factors, the effective utilization of customer complaint data can provide valuable support for continuous improvement initiatives.

This study aims to evaluate the performance of different clustering algorithms in grouping failure records associated with customer complaints and to determine the most suitable approach for supporting failure analysis, root-cause investigation, and preventive actions. The dataset consists of 22,153 service records obtained from an HVAC manufacturer. Following data preprocessing, including missing value treatment, categorical variable encoding, and normalization, four clustering algorithms were applied and compared: Hierarchical Clustering, K-Means, Fuzzy C-Means, and DBSCAN. Clustering performance was assessed using the Silhouette Coefficient, one of the most widely used cluster validity indices for evaluating clustering quality [1], while the resulting cluster structures were examined in terms of interpretability and practical relevance for failure analysis.

The results revealed distinct failure profiles within the complaint records. Across all methods, a large cluster representing routine service cases and a smaller critical cluster associated with prolonged failure durations were identified. This critical cluster was primarily linked to pump and turbine components, highlighting areas that require priority attention for quality improvement and preventive maintenance. Comparative evaluation of the clustering results showed that K-Means achieved the highest clustering quality and provided the most interpretable cluster structure, making it the most suitable method for failure profiling in this dataset. The proposed framework enables the systematic identification of critical failure groups from customer complaints and supports data-driven decision-making for root-cause analysis, service process improvement, and failure prevention in the HVAC industry.

Keywords: Clustering Algorithms, Failure Profiling, Customer Complaints, Quality Improvement, Root Cause Analysis

References

[1] Ikotun, A.M., Habyarimana, F., & Ezugwu, A.E. (2025). Cluster validity indices for automatic clustering: A comprehensive review. Heliyon, 11 (2), e41953.

✉ Corresponding Author Email: *6066007@bakircay.edu.tr*

An integrated AHP-based MCDM module for vendor quotation ranking in SAP ABAP

Eszter Kiss, Anett Rácz ✉

University of Debrecen,Faculty of Informatics, Department of Applied Mathematics and Probability Theory, Debrecen, Hungary

Abstract

Pairwise comparison methods have gained widespread popularity in business practice due to their inherent simplicity, while the Analytic Hierarchy Process (AHP) built upon them [1] extends this foundation into a transparent yet sophisticated multi-criteria decision making (MCDM) framework, capable of structuring and resolving complex decision problems involving both quantitative and qualitative criteria. In parallel, SAP enterprise resource planning (ERP) systems remain the dominant platform for corporate operations worldwide, with the SAP Materials Management (MM) module forming the backbone of procurement processes in a large share of mid-sized and large enterprises [2]. Given the prevalence of both AHP and SAP independently, a natural opportunity emerges: embedding one of the most popular decision-support methodologies directly into one of the most widely used enterprise systems.

This talk presents the design and implementation of an AHP-based decision support module developed in the SAP ABAP environment [3], aimed at supporting purchase order decision-making. The module ranks incoming vendor quotations received for a given purchase requisition using the AHP methodology. It operates directly on the standard database tables of the SAP MM module, leveraging existing vendor evaluation criteria and their custom weightings already configured in the system. As such, the module does not replace but complements and extends the existing SAP infrastructure, offering a practical example of how academic decision-theory methods can be operationalized within real-world enterprise software.

Keywords: Multi-criteria decision making, Analytic Hierarchy Process, Enterprise Decision Support

References

[1] Saaty, T.L. (1980). The Analytic Hierarchy Process: Planning, Priority Setting, Resource Allocation. McGraw-Hill, New York

[2] SAP SE. SAP Materials Management (MM) – Product Documentation. SAP Help Portal. https://help.sap.com

[3] SAP SE. *ABAP Documentation*. SAP Help Portal. https://help.sap.com/doc/abapdocu

✉ Corresponding Author Email: *anett.racz@inf.unideb.hu*

Homoclinical Structure of Impulsive SICNNs

Ruşen Kaya[1,3]✉, Fatma Tokmak Fen[2], Mehmet Onur Fen[3]

[1] *Gazi University, Graduate School of Natural and Applied Sciences, Ankara, Türkiye*
[2] *Gazi University, Department of Mathematics, Ankara, Türkiye*
[3] *TED University, Department of Mathematics, Ankara, Türkiye*

Abstract

In this study, we take into account a class of shunting inhibitory cellular neural networks (SICNNs) with impulse actions. It is rigorously proved under sufficient conditions that homoclinic and heteroclinic outputs are generated. The presence of impulses allows for the modeling of situations where sudden changes occur in the state of the network. SICNNs have applications in various fields such as image processing, adaptive pattern recognition, perception, vision, and robotics. These application areas highlight the wide-ranging impact of our theoretical results. Appropriate numerical simulations are presented to approve the theory.

Keywords: Shunting inhibitory cellular neural networks, impulse actions, homoclinic and heteroclinic outputs

References

[1] Chua, L.O., & Yang, L. (1988). Cellular neural networks: Theory. IEEE Transactions on Circuits and Systems, 35, 1257–1272.
[2] Bouzerdoum, A., & Pinter, R.B. (1993). Shunting inhibitory cellular neural networks: Derivation and stability analysis. IEEE Transactions on Circuits and Systems I: Fundamental Theory and Applications, 40, 215–221.
[3] Haddad, W.M. (2020). Condensed matter physics, hybrid energy and entropy principles, and the hybrid first and second laws of thermodynamics. Communications in Nonlinear Science and Numerical Simulation, 83, 105096.
[4] Liu, J., Yan, L., Xu, F., & Lai, M. (2018). Homoclinic solutions for Hamiltonian system with impulsive effects. Advances in Difference Equations, 2018, 326.
[5] Li, X., Bohner, M., & Wang, C.-K. (2015). Impulsive differential equations: periodic solutions and applications. Automatica, 52, 173–178.
[6] Samoilenko, A.M., & Perestyuk, N.A. (1995). Impulsive Differential Equations. World Scientific, Singapore.

✉ Corresponding Author Email: *rusen.kaya@tedu.edu.tr*

A Stochastic Hybrid Energy System Model Consisting of Natural Gas, Hydroelectric and Wind Power: Stability Analysis and Carbon Emission Dynamics

Ahmet Çoban, Necati Özdemir

Balikesir University, Department of Maths, Balikesir, Turkiye

Abstract

The increasing penetration of renewable energy resources into modern power systems has introduced significant uncertainties in energy generation and system operation. To address these challenges, this study proposes a stochastic hybrid energy system model consisting of natural gas, hydropower, and wind energy sources, together with electricity demand and carbon emission dynamics. The proposed model is formulated as a system of nonlinear differential and stochastic differential equations, where wind power generation and electricity demand are affected by random fluctuations represented through Brownian motion processes.

The existence of a positive equilibrium point is established, and the boundedness and positivity of system solutions are investigated. Local stability properties are analyzed by deriving the Jacobian matrix and examining the associated eigenvalues at the equilibrium point. Furthermore, a Lyapunov-based framework is developed to study deterministic asymptotic stability, while stochastic stability is investigated using Itô–Lyapunov theory. Sufficient conditions guaranteeing exponential mean-square stability are obtained.

To validate the theoretical findings, numerical simulations are performed using deterministic solvers and the Euler–Maruyama method for the stochastic model. Monte Carlo simulations are conducted to evaluate the influence of renewable energy uncertainty on system performance and carbon emission dynamics. The results demonstrate that the proposed hybrid energy system remains stable under realistic stochastic disturbances and provides an effective framework for analyzing the interaction between energy production, demand fluctuations, and environmental impacts.

Keywords: Hybrid energy systems, stochastic differential equations, hydropower, wind energy, natural gas, carbon emissions, Lyapunov stability, Itô calculus, mean-square stability, Monte Carlo simulation.

References

[1] A. Pepiciello and J. L. Domínguez-García, "Small-signal stability analysis of uncertain power systems: A comprehensive survey," Renewable and Sustainable Energy Reviews, vol. 200, Art. no. 114576, Aug. 2024, doi: 10.1016/j.rser.2024.114576.

[2] H. Mushtaq and N. Senroy, "Stochastic Differential-Algebraic Equations in Power Systems–Semi Implicit Approach," IEEE Transactions on Power Systems, vol. 39, no. 1, pp. 2353–2356, Jan. 2024, doi: 10.1109/TPWRS.2023.3320892.

✉ Corresponding Author Email: *ahmetcobanea@gmail.com*

A Carbon-Aware Algorithm Selection Framework for Wind Turbine Power Prediction Using SCADA Data

Melike Sultan Karasu Asnaz ✉

Balikesir University, Industrial Engineering Department, Balikesir, Türkiye

Abstract

Wind turbine power prediction is essential for renewable energy management, grid reliability, and sustainable energy planning. Machine learning algorithms are widely used for this task because they can model nonlinear relationships between turbine operating variables and generated power [1]. However, model selection in wind power forecasting is generally based on predictive accuracy, while the computational cost and carbon footprint of training, testing, and hyperparameter tuning are often ignored. Recent studies in sustainable computing emphasize the need to evaluate algorithms not only by performance but also by carbon-related impacts [2], and computational carbon assessment methods provide a basis for quantifying the environmental cost of algorithmic workloads [3], [4]. This study proposes a carbon-aware algorithm selection framework for wind turbine power prediction using 10-minute SCADA data. The dataset includes active power, wind speed, theoretical power curve, and wind direction, together with derived time-based features such as hour, month, season, week, and day/night indicators. Representative machine learning algorithms from different model families are comparatively evaluated. Predictive performance is assessed using standard regression-based indicators, while computational performance is examined through training time, inference time, estimated energy consumption, and computation-related CO_2 emissions. The carbon impact of each algorithm is estimated through a carbon accounting tool-based procedure. The proposed framework introduces a multi-objective perspective by considering prediction accuracy, computational time, and carbon impact simultaneously. By integrating carbon-related indicators into algorithm evaluation, the study supports transparent, responsible, and sustainability-oriented model selection for wind energy forecasting applications.

Keywords: carbon-aware algorithm selection, wind turbine power prediction, computational carbon footprint, sustainable artificial intelligence.

References

[1] Haq, I. U., & Kumar, S. (2025). Machine learning approaches for wind power forecasting: A comprehensive review. *Discover Applied Sciences, 7*, 1139.

[2] Spillo, G., De Filippo, A., Musto, C., Milano, M., & Semeraro, G. (2026). Balancing carbon footprint and algorithm performance in recommender systems: A comprehensive benchmark. *Sustainable Computing: Informatics and Systems, 49*, 101286.

[3] Lannelongue, L., Grealey, J., & Inouye, M. (2021). Green Algorithms: Quantifying the carbon footprint of computation. *Advanced Science, 8*(12), 2100707.

[4] Bouza Heguerte, L., Bugeau, A., & Lannelongue, L. (2023). How to estimate carbon footprint when training deep learning models? A guide and review. *Environmental Research Communications, 5*(11), 115014.

✉ Corresponding Author Email: karasu@balikesir.edu.tr

Heating Energy Demand Forecasting Using Different Regression Techniques Based on the Building Wall Envelope Heat Transfer Coefficient

Okan Kon, İsmail Caner ✉

Balikesir University, Mechanical Engineering Department, Balikesir, Türkiye

Abstract

Buildings are composed of envelope component such as walls in different directions, characterized by a specific heat transfer coefficient (HTC). HTC is determined by the thermal properties of these components and is a key parameter affecting the thermal performance of buildings. Using HTC values, the heat loss coefficient (HLC) can be calculated and used to estimate heating energy demand. Indoor and outdoor air temperatures are also important parameters in thermal performance analyses. Indoor temperature is generally assumed to be constant to maintain occupant thermal comfort. In addition, solar radiation and wind speed influence building energy consumption. Solar radiation provides heat gains that reduce heating demand, whereas wind speed affects convective heat transfer and increases heat losses. This study investigates the forecasting of heating energy demand using the Siviour method, Simple Linear Regression (SLR), and Multiple Linear Regression (MLR). Previous studies have mainly focused on residential buildings and the prediction of heating and cooling energy demand [1–6]. In contrast, this study applies these methods to different building types, including workshops, restaurants, airports, military barracks, and swimming pools wall. To ensure consistency, HLC values were maintained within an average variation of ±10%. The relationships between model inputs and outputs were examined, and the key factors affecting heating energy demand were identified. The SLR model uses indoor and outdoor temperatures, equivalent temperatures, and HTC values as input parameters. Equivalent temperature depends on convective and radiative heat transfer coefficients, with outdoor wind speed being a major factor affecting convective heat transfer. The results demonstrate the applicability of regression-based methods for forecasting heating energy demand in various buildings for the exterior wall in different directions.

Keywords: Heat transfer coefficient (HTC), building energy demand prediction, regression methods, equivalent temperature, solar heat gain

References

[1] Jay, A., Campagna, K., Pacquaut, A., Juricic, S., & Challansonnex, A. (2024). Extending the validity of co-heating tests to warmer and sunnier weather conditions using an equivalent exterior temperature. Energy and Buildings, 319, 114483.

[2] Jack, R., Loveday, D., Allinson, D., & Lomas, K. (2018). First evidence for the reliability of building co-heating tests. Building Research & Information, 46(4), 383-401.Holland, M. (2004).

[3] Ritosa, K., Saelens, D., & Roels, S. (2023, December). How reliable is the co-heating test? In *Journal of Physics: Conference Series* (Vol. 2654, No. 1, p. 012060). IOP Publishing.

[4] Law, A., & Wong, J. P. (2020). Application of the Co-heating test in Australian climates. *Energy and Buildings*, *224*, 110153.

[5] Farmer, D., Johnston, D., Miles-Shenton, D. (2016). Obtaining the heat loss coefficient of a dwelling using its heating system (integrated coheating). *Energy and Buildings*, 117, 1-10.

[6] Kon, O., Yuksel, B., Karaoglan, A. D. (2021). Modeling and Analysis of the Relationship with Regression Equation between Heating/Cooling Load Change and Outdoor Meteorological data of Business and Service Buildings. *International Conference on Applied Mathematics in Engineering (ICAME) September 1-3, Balikesir, Turkey.*

✉ Corresponding Author Email: *ismail@balikesir.edu.tr*

Cooperative Value Analysis of Repowering Strategies in Heterogeneous Wind Farms under Wake Interactions

Yunus Eroğlu ✉

Gaziantep University, Industrial Engineering Department, Gaziantep, Türkiye

Abstract

Repowering offers an economic opportunity to a number of wind farms built in the first growth phase. Turbine designs have advanced considerably resulting in increased rated power, higher rotor diameter, and improved energy generation per swept area. However the re-powering of an existing wind farm with a more powerful generation of turbine technology presents a difficult decision problem, in which effects of wind-wake, limits of usable land area, installation and decommissioning costs of two turbine-generations, and their co-existence on the wind-farm site, can have an impact on the overall project performance and economics. Thus the best performing technology in absolute may be the worst one in relative as an investment alternative. A framework for analyzing the cooperative value of different technology adoption decisions in a repowered wind farm with heterogeneous turbines was presented in this work. Each generation's economic impact to the overall farm benefit in the presence of the wake effect was examined. A wind farm comprising both legacy and next-generation wind turbine technologies is assessed. A variety of re-powering strategies, involving both a mix and a full replacement approach, are analyzed. The wake-aware wind farm layout optimization problem for each coalition of technologies is formulated and solved by means of a metaheuristic optimization technique. Jensen wake model is adopted for simulating the energy production whereas the economic effectiveness of each coalition is evaluated using the Net Present Value (NPV) considering installation, Operation & Maintenance, decommissioning, and scrap costs. The coalition values obtained were discussed using cooperative game theory. Technology selection, which creates highest level of cooperation under particular operation condition can be identified based on the framework.

Keywords: Wind farm repowering, Cooperative game theory, Wake-aware layout optimization

✉ Corresponding Author Email: *eroglu.yunus@gmail.com*, *eroglu@gantep.edu.tr*

Impact of Core Materials on Performance of Wound Rotor Synchronous Generators

Furkan Keskin[1]✉, Oktay Karakaya[2], Murat Erhan Balci[3]

[1]*ISBIR Electric Co., R&D Department, Balikesir, Türkiye*
[2]*Balikesir University, Bigadic Vocational School, Balikesir, Türkiye*
[3]*Balikesir University, Dept. of Electrical and Electronics Engineering, Balikesir, Türkiye*

Abstract

In recent years, advanced magnetic materials have been considered to reduce core losses and improve the efficiency of electrical machines [1]. Accordingly, the effects of different magnetic core materials on the performance of electrical machines are analysed in several studies [2, 3]. However, there is relatively limited interest in such analyses on wound rotor synchronous generators (WRSGs) [4], widely used in conventional diesel generator sets. In this study, the performance of several magnetic core materials including conventional non-oriented electrical steels (50JN350, 50JN470, and 50JN600) and advanced low-loss alternatives (20JNHF1300 and VACOFLUX 48) is evaluated for use in the design of a 300 kVA, 400 V, 50 Hz, 1500 rpm, salient-pole WRSG. For each material, the generator design is parametrically optimized to achieve maximum efficiency using the RMxprt in the Ansys Maxwell environment. The number of wires per conductor, the number of conductors per slot, and the core length are considered design variables. The optimization results are validated by 2D FEM analysis in the same software. It is found that, depending on the magnetic material, generator efficiency ranges from 94.40% to 96.03% and machine weight from 434.54 kg to 502.12 kg. The advanced materials, VACOFLUX 48 and 20JNHF1300, provide a more favourable efficiency–weight performance than conventional ones. However, their high material costs may limit their commercial use in diesel generators. Among the conventional materials, 50JN350 achieves the highest efficiency and the lowest machine weight, and 50JN600 offers the lowest active material cost at the expense of the highest machine weight.

Keywords: Efficiency optimization, magnetic core materials, wound rotor, synchronous generators.

Acknowledgements

This study was carried out within the scope of an R&D project conducted by ISBIR Electric Co.

References

[1] Elgamli, E., & Anayi, F. (2023). Advancements in electrical steels: A comprehensive review of microstructure, loss analysis, magnetic properties, alloying elements, and the influence of coatings. *Applied Sciences*, 13(18), 10283.

[2] Esenboğa, B. (2024). Comparative performance analysis of PMSGs using various core materials for wind turbine application. *OKU Journal of Institute of Science and Technology*, 7(5), 2217-2231.

[3] Fernando, N., Vakil, G., Arumugam, P., Amankwah, E., Gerada, C., & Bozhko, S. (2017). Impact of soft magnetic material on design of high-speed permanent-magnet machines. *IEEE Transactions on Industrial Electronics*, 64(3), 2415-2423.

[4] Biasion, M., Kowal, D., Moghaddam, R. R., & Pastorelli, M. (2022, October). Influence of the lamination material and rotor pole geometry on the performance of wound field synchronous machines. *In 2022 IEEE Energy Conversion Congress and Exposition (ECCE)* (pp. 1-8), IEEE.

✉ Corresponding Author Email: furkan.keskin@isbirelektrik.com.tr

Design of an Intelligent Student Tracking System Based on Educational Data Mining

Abdullah Usame Gündeşli ✉, Hüseyin Avni Es

Karadeniz Technical University, Industrial Engineering, Trabzon, Turkey

Abstract

Educational Data Mining is an interdisciplinary field that analyzes data generated by students and learning environments to better understand learning processes and support data-driven educational decision-making [1]. The analysis of academic performance data provides valuable insights for monitoring student development and improving educational management [2]. This study proposes an EDM-based analytical framework for monitoring students' academic performance across semesters and identifying anomalous changes in their academic trajectories. The framework is based on the Performance–Success–Balance (PSB) model, inspired by the Recency–Frequency–Monetary (RFM) approach widely used in customer analytics. Student performance is represented using three indicators: semester grade point average (GPA), the number of successfully completed courses, and the total earned ECTS credits. These indicators are discretized and scored on a scale of 1–5 using a K-Means-based approach and subsequently transformed into interpretable academic performance segments through rule-based segmentation.

The proposed framework was applied to anonymized data from the Department of Industrial Engineering at a university in Türkiye. Using data covering eight consecutive semesters, student performance profiles were monitored and inter-semester segment transitions were analyzed from an anomaly detection perspective. The results indicate that the proposed model effectively identifies meaningful changes in academic performance and provides interpretable analytical outputs for decision-makers. By integrating segmentation and anomaly detection within a unified framework, this study contributes a practical application to the EDM literature and demonstrates the potential of longitudinal academic data for student monitoring and performance management.

Keywords: Educational Data Mining, Segmentation, Anomaly Detection, K-Means.

References

[1] Baker, R.S.J.d. and Yacef, K., 2009. The state of educational data mining in 2009: A review and future visions. Journal of Educational Data Mining, 1(1), pp.3–17.

[2] Romero, C. and Ventura, S., 2020. Educational data mining and learning analytics: An updated survey. Wiley Interdisciplinary Reviews: Data Mining and Knowledge Discovery, 10(3), e1355.

✉ Corresponding Author Email: *agundesli06@gmail.com*

Forecasting Türkiye's Hourly Net Load via LSTM Models with Different Input Configurations

Burak Aşkın[1]✉, Hüseyin Avni Es[2]

[1] *Bayburt University, Faculty of Applied Sciences, Department of Management Information Systems, Bayburt, Turkey*
[2] *Karadeniz Technical University, Faculty of Engineering, Department of Industrial Engineering, Trabzon, Turkey*

Abstract

Rapid growth of renewable energy sources is changing the operating conditions of power systems by increasing variability in the balance between electricity demand and generation. Net load, defined as electricity consumption minus variable renewable generation, therefore provides a more operationally meaningful target for short-term planning, reserve scheduling, and balancing decisions. Recent studies emphasize that renewable-integrated systems require forecasting models capable of representing nonlinear temporal behavior and the changing effects of input variables [1,2]. Long Short-Term Memory (LSTM) networks are widely used for such problems because they can learn sequential dependencies in time-series data [3].

This study examines how the design of historical inputs affects hourly net load forecasting performance for Türkiye. Three input designs are compared: sliding window, selected lag points, and single vector. The LSTM models are constructed using different combinations of historical net load, installed capacity, and sine-cosine time representations. To evaluate the effect of input design more clearly, similar network structures and identical data sets are used across the models. The results are compared with a Seasonal Autoregressive Integrated Moving Average (SARIMA) model and evaluated using mean absolute percentage error, mean absolute error, root mean square error, and post-error ratio.

The best result is obtained by the sliding-window model that uses historical net load, installed capacity, and time representations. This model achieves a mean absolute percentage error of 1.267%, whereas the best selected-lag and single-vector models achieve 1.633% and 1.811%, respectively. The SARIMA model remains considerably behind the LSTM models. The findings indicate that the way historical information is organized before being presented to LSTM networks is a key factor in improving net load forecasting accuracy.

Keywords: Net load forecasting, LSTM, input design, sliding window, renewable energy.

References

[1] Tziolis, G., Spanias, C., Theodoride, M., Makrides, G., & Georghiou, G. E. (2025). Net load forecasting review: Methodologies, input variables, and future directions. Renewable and Sustainable Energy Reviews, 190, 114047.
[2] Silva-Rodriguez, J., Luna-Rubio, R., Gonzalez-Rodriguez, A., & Cerda-Villafana, G. (2024). LSTM-based net load forecasting for wind and solar power-equipped microgrids. Forecasting, 6(1), 80–97.
[3] Hochreiter, S., & Schmidhuber, J. (1997). Long short-term memory. Neural Computation, 9(8), 1735–1780.

✉ Corresponding Author Email: *burakaskin@bayburt.edu.tr*

Data-Driven Soiling Loss Estimation and Cleaning Schedule Optimization for a Rooftop Photovoltaic System

Melike Sultan Karasu Asnaz[1]✉, Yusuf Toprak[2]

[1] *Balikesir Univeristy, Indusrial Engineering Department, Balıkesir, Türkiye*
[2] *Sarıbekir Ambalaj, Balıkesir, Türkiye*

Abstract

Soiling is an important cause of performance loss in photovoltaic (PV) systems. However, cleaning is often planned by fixed schedules rather than site-specific data [1,2]. This study proposes an AI-assisted and optimization-oriented approach to estimate soiling losses and determine suitable cleaning days for a rooftop PV system. The system has an installed capacity of 1131 kWp and is monitored using daily performance, meteorological, and air-quality data, including performance ratio, cell temperature, ambient temperature, relative humidity, precipitation, wind speed and direction, dew point, global horizontal irradiance, and PM10 concentration. The methodology starts with preprocessing PV data and correcting temperature and irradiance effects to distinguish abnormal performance reductions. Natural cleaning events are identified from precipitation data, and soiling rates during dry periods are estimated. PM10 exposure, humidity, wind conditions, rainfall, and dry-period duration are then examined to explain the temporal change in soiling losses. Based on these indicators, a machine learning-based algorithm is developed to forecast soiling accumulation and suggest candidate cleaning dates. Cleaning scenarios are compared by using cleaning cost and electricity price, so recovered energy gain can be evaluated together with operational expenditure [3,4]. The results show that soiling losses are not constant and are related to weather conditions and dry-period characteristics. Therefore, fixed periodic cleaning may not always be suitable. Instead, optimization-based cleaning decisions can help identify more profitable maintenance actions by balancing energy gain and cleaning cost. The proposed approach provides a practical basis for predictive maintenance, techno-economic optimization, and AI-based performance management in rooftop PV systems.

Keywords: PV soiling, cleaning schedule optimization, predictive maintenance, techno-economic decision support

References

[1] Fernández-Solas, Á., Montes-Romero, J., Micheli, L., Almonacid, F., & Fernández, E.F. (2022). Estimation of soiling losses in photovoltaic modules of different technologies through analytical methods. *Energy*, 244, 123173.
[2] Sharma, S., Raina, G., Yadav, S., & Sinha, S. (2023). A comparative evaluation of different PV soiling estimation models using experimental investigations. *Energy for Sustainable Development*, 73, 280–291.
[3] Duman, S., Kahraman, H.T., Sonmez, Y., Guvenc, U., Kati, M., & Aras, S. (2022). A powerful meta-heuristic search algorithm for solving global optimization and real-world solar photovoltaic parameter estimation problems. *Engineering Applications of Artificial Intelligence*, 111, 104763.
[4] Bora, A. (2023). *Data-Driven Estimation of Soiling Loss and Optimal Cleaning Schedule for a Utility-Scale PV Plant*. Master's thesis, University of Waterloo, Waterloo, Ontario, Canada.

✉ Corresponding Author Email: *karasu@balikesir.edu.tr*

Residual co-implication based fuzzy partial metric spaces: An application to image denoising

Elif Güner✉, Azra Nur Çelik, Halis Aygün

Department of Mathematics, Kocaeli University, Umuttepe Campus, 41380, Kocaeli/Türkiye

Abstract

In recent years, fuzzy metric spaces and fuzzy partial metric spaces have attracted considerable attention due to their ability to generalize classical metric structures and model uncertainty in a more flexible and nuanced manner. In particular, fuzzy partial metrics extend fuzzy metrics by allowing different self-distances for points. In this paper, we present a new approach to the concept of a fuzzy partial metric (FPM) space by using residual co-implication operators instead of residual implications, called residual co-implication based fuzzy partial metric spaces (RCB-FPMSs). This framework provides an alternative way of measuring similarity and uncertainty and enlarges the class of available fuzzy partial metric structures. Also, the proposed concept generalizes the notion of t-conorm based fuzzy metric spaces introduced by Grigorenko et al. [3]. We investigate fundamental properties of RCB-FPM spaces and compare them with existing FPM spaces. Furthermore, new examples of RCB-FPMs are constructed by means of continuous Archimedean t-conorms. Finally, we demonstrate the applicability of the proposed metric structure to image denoising problems.

Keywords: residuum operators, fuzzy metric spaces, fuzzy partial metric spaces, image denoising

References

[1] Aygün, H., Güner, E., Minana, J. J., & Valero, O. (2022). Fuzzy partial metric spaces and fixed point theorems. Mathematics, 10(17), 3092.
[2] Gregori, V., Minana, J. J., & Miravet, D. (2019). Fuzzy partial metric spaces. International Journal of General Systems, 48(3), 260-279.
[3] Grigorenko, O., Minana, J. J., Sostak, A., & Valero, O. (2020). On t-conorm based fuzzy (pseudo) metrics. Axioms, 9(3), 78.

✉ Corresponding Author Email: *elif.guner@kocaeli.edu.tr*

Evaluating Machine Learning Classifiers for Market Prediction in the Traveling Purchaser Problem

Aykut Sen[1]✉, Ilker Kucukoglu[1], Aysun Yurttas Gunes[2], Hacer Ozden Ayna[2], Ismail Naci Cangul[2]

[1] *Bursa Uludag University, Department of Industrial Engineering, Bursa, Turkey*
[2] *Bursa Uludag University, Department of Mathematics, Bursa, Turkey*

Abstract

The Traveling Purchaser Problem (TPP) is a combinatorial optimization problem in which a purchaser must visit a selected subset of markets to obtain all required products while minimizing the overall cost [1]. TPP combines procurement decisions with routing decisions, in which a number of product demands are satisfied from different-located markets. The aim of the problem is to minimize the total traveling and procurement cost of the purchaser. This study proposes a machine learning framework to predict market membership in optimal TPP solutions. Using a number of graph-based features describing market characteristics and connectivity, we evaluated Random Forest, XGBoost, LightGBM, SVM, and MLP classifiers. GroupShuffleSplit and GroupKFold cross-validation were employed to ensure instance-level separation and prevent data leakage.

Experiments were conducted on two datasets of increasing size and diversity, ranging from single-size instances to a full multi-size benchmark set. Results consistently showed that predictive performance improved as the training data became more diverse. On the smallest dataset, the optimized Random Forest model achieved an accuracy and F1 score of about 0.76. Performance increased further on the combined two-size dataset, where both Random Forest and XGBoost reached accuracies above 0.85. The best results were obtained on the full multi-size dataset, with Random Forest achieving 0.89 accuracy and 0.89 F1 score. These findings demonstrate that incorporating a wider variety of problem instances substantially improves the mode's ability to generalize across different TPP configurations.

The result indicates that TPP structural features contain sufficient information to accurately predict market participation in optimal solutions, highlighting the potential of integrating ML predictions with exact and heuristic optimization approaches.

Keywords: Traveling purchaser problem, machine learning, classification, graph-based feature

Acknowledgements

This study was supported by Bursa Uludag University Research Projects Coordination Office under the Grant Number FYL-2026-2659 and FGA-2025-2204. The authors thank to BUU BAP Unit for their supports.

References

[1] Manerba, D., Mansini, R., & Riera-Ledesma, J. (2017). The Traveling Purchaser Problem and its variants. European Journal of Operational Research, 259:1–18. https://doi.org/10.1016/J.EJOR.2016.12.017.

✉ Corresponding Author Email: *aykutsen@uludag.edu.tr*

Carbon-Conscious Energy Efficiency Assessment Using Explainable Artificial Intelligence and Multi-Criteria Optimization: Evidence from Borsa Istanbul Firms

Ahmet Akusta[1]✉, Hasan Hüseyin Yıldırım[2], Emre Akusta[3]

[1] *Rectorate, Konya Technical University, Turkey*
[2] *Finance and Banking Department, Balikesir University, Turkey*
[3] *Department of Economics, Kirklareli University, Kirklareli, Turkiye*

Abstract

Corporate sustainability pressures require decision-support models that jointly assess carbon exposure, energy efficiency and financial viability. This study develops an explainable artificial intelligence-based multi-criteria optimization framework to evaluate the carbon-conscious energy efficiency performance of Borsa Istanbul firms. The empirical design uses ESG, environmental, climate, energy and financial indicators obtainable from Refinitiv/LSEG. Since ESG ratings may vary across providers due to differences in scope, measurement and weighting [1], the model combines ESG information with firm-level carbon and energy indicators. Carbon intensity, energy intensity, carbon productivity, energy productivity, environmental pillar score, resource use score, emissions score, ESG/ESGC score, profitability, firm size and leverage are constructed. Carbon and energy intensity are treated as cost criteria, while ESG, environmental and financial indicators are treated as benefit criteria. Objective weights are obtained using Entropy and CRITIC methods [2,3]. A Carbon-Conscious Energy Efficiency Index is then calculated through TOPSIS and/or VIKOR, which rank firms according to their closeness to ideal or compromise solutions [4]. Firms are grouped into high, medium and low performance classes. XGBoost, LightGBM, CatBoost and artificial neural networks are used to predict these classes, while SHAP analysis explains the contribution of ESG, carbon, energy and financial variables to the model outputs [5,6]. Sensitivity checks compare alternative weighting and ranking schemes across sectors and years. The proposed framework integrates sustainability, carbon efficiency, energy management and financial performance into a transparent decision-support model for investors, managers and policymakers.

Keywords: Artificial intelligence, energy efficiency, carbon intensity, ESG, multi-criteria optimization, explainable AI, Borsa Istanbul

References

[1] Berg, F., Kölbel, J.F., & Rigobon, R. (2022). Aggregate confusion: The divergence of ESG ratings. Review of Finance, 26(6), 1315-1344. https://doi.org/10.1093/rof/rfac033.
[2] Shannon, C.E. (1948). A mathematical theory of communication. The Bell System Technical Journal, 27(3), 379-423; 27(4), 623-656.
[3] Diakoulaki, D., Mavrotas, G., & Papayannakis, L. (1995). Determining objective weights in multiple criteria problems: The CRITIC method. Computers & Operations Research, 22(7), 763-770. https://doi.org/10.1016/0305-0548(94)00059-H.
[4] Opricovic, S., & Tzeng, G.H. (2004). Compromise solution by MCDM methods: A comparative analysis of VIKOR and TOPSIS. European Journal of Operational Research, 156(2), 445-455. https://doi.org/10.1016/S0377-2217(03)00020-1.
[5] Bentéjac, C., Csörgő, A., & Martínez-Muñoz, G. (2021). A comparative analysis of gradient boosting algorithms. Artificial Intelligence Review, 54, 1937-1967. https://doi.org/10.1007/s10462-020-09896-5.
[6] Lundberg, S.M., Erion, G., Chen, H., DeGrave, A., Prutkin, J.M., Nair, B., Katz, R., Himmelfarb, J., Bansal, N., & Lee, S.I. (2020). From local explanations to global understanding with explainable AI for trees. Nature Machine Intelligence, 2, 56-67. https://doi.org/10.1038/s42256-019-0138-9.

✉ Corresponding Author Email: *aakusta@ktun.edu.tr*

A Truck–Drone Routing Problem for Post-Earthquake Damage Assessment

Ilker Kucukoglu✉, Emine Es Yurek, Melih Ali Pacaci, Nidanur Basocak, Yaren Ozbek

Bursa Uludag University, Industrial Engineering Department, Bursa, Turkey

Abstract

Rapid damage assessment during the first hours following a major earthquake is essential for effective search-and-rescue operations and disaster response planning. However, damaged transportation infrastructure frequently prevents ground vehicles from accessing affected regions, while the limited flight endurance of unmanned aerial vehicles (UAVs) restricts their operational coverage [1, 2]. To address these challenges, this study proposes a novel truck–drone routing problem for post-earthquake damage assessment, in which ground vehicles transport drones to strategically selected launch locations, enabling efficient aerial imaging of inaccessible areas.

Unlike the majority of truck–drone routing studies that primarily focus on humanitarian aid distribution or parcel delivery, the proposed problem is specifically designed for post-disaster damage assessment. The originality of the study lies in simultaneously determining truck routes, drone routes, and drone launch locations while maximizing the total imaging benefit within a limited operational time. Furthermore, the model distinguishes between mandatory imaging locations, including hospitals and fire stations that are vital for emergency response, and optional imaging locations, whose priorities are determined according to population density and earthquake hazard levels. A mixed-integer linear programming (MILP) model is developed to maximize the total imaging benefit while considering truck routing constraints, drone battery limitations, synchronization between trucks and drones, operational time restrictions, and mandatory coverage requirements.

Since exact optimization becomes computationally expensive for realistic large-scale disaster scenarios, a solution construction heuristic algorithm is also developed. To demonstrate the applicability of the approach, a realistic case study based on the Nilüfer district of Bursa, Türkiye, is developed using GIS data. Computational experiments indicate that the proposed heuristic generates practicable solutions within short computational times for real-life problems.

Keywords: Disaster management, drone routing, mixed-integer programming

Acknowledgements

This study is supported by TUBİTAK 2209-A University Students Research Projects Support Program with the project ID TBTK-0215-2573.

References

[1] Adsanver, B., Coban, E., & Balcik, B. (2021). Drone routing for post-disaster damage assessment. Dynamics of Disasters, 169, 1-29.

[2] Faiz, T.I., Vogiatzis, C., Liu, J., & Noor-E-Alam, M. (2022). A robust optimization framework for two-echelon vehicle and UAV routing for post-disaster humanitarian logistics operations. Networks, 84(2), 200-219.

✉ Corresponding Author Email: *ikucukoglu@uludag.edu.tr*

FEA-Based Design and Analysis of a Brushless Excitation Machine for a Medium-Voltage Synchronous Generator

Muhammed Berat Altinok[1]✉, Oktay Karakaya[2], Murat Erhan Balci[3], Cuneyt Ceyhan[1]

[1] *ISBIR Electric Co., R&D Department, Balikesir, Türkiye*
[2] *Balikesir University, Bigadic Vocational School, Balikesir, Türkiye*
[3] *Balikesir University, Dept. of Electrical and Electronics Engineering, Balikesir, Türkiye*

Abstract

In diesel-generator applications, the brushless excitation machine (BEM) is responsible for supplying the field current demanded by the synchronous generator (SG). In conventional brushless excitation systems, the AC voltage induced in the rotating armature winding of the BEM is rectified by a rotating uncontrolled diode bridge and delivered to the field winding of the SG [1, 2]. The design and performance analysis of BEMs for aircraft wound-rotor synchronous machines have gained increasing attention in the recent literature [3]. However, there are limited studies on the design and analysis of BEMs used in conventional SGs, particularly considering effect of the rotating diode rectifier on the system [1, 4]. This paper presents a 2D finite-element-based design and analysis of a 16-pole BEM for a 6.3 kV, 2750 kVA, 50 Hz, 1500 rpm salient-pole SG using Ansys Maxwell software. The coupled operation of the BEM and the rotating diode rectifier, loaded by an equivalent resistance representing the SG field winding, is simulated using Circuit Editor. The voltage, current, and active power at the output of the rectifier, and the magnetic flux density, total losses, and efficiency of the BEM are analysed over the BEM's excitation current (I_exc) range of 1–6 A. For I_exc=6A, the rectifier output voltage and current reach 304 V and 152 A corresponding to the rated output power of 46.2 kW. Under the same operating condition, the maximum local magnetic flux density is nearly 1.8 T, and the total loss and efficiency are calculated as 3.855 kW and 92.3%.

Keywords: Brushless exciters, design, modelling, synchronous generators, finite element analysis.

Acknowledgements

This study was carried out within the scope of an R&D project conducted by ISBIR Electric Co.

References

[1] Nuzzo, S., Galea, M., Gerada, C., & Brown, N. (2017). Analysis, modeling, and design considerations for the excitation systems of synchronous generators. *IEEE Transactions on Industrial Electronics*, *65*(4), 2996-3007.

[2] Nøland, J. K., Nuzzo, S., Tessarolo, A., & Alves, E. F. (2019). Excitation system technologies for wound-field synchronous machines: Survey of solutions and evolving trends. *IEEE Access*, *7*, 109699-109718.

[3] Bian, W., Zhang, Z., Li, L., Li, J., & Li, Y. (2024). Performance improvement of brushless exciter for aircraft wound rotor synchronous machine based on magnetic slot wedge. *IEEE Transactions on Magnetics*, *60*(9), 1-6.

[4] Gorginpour, H. (2018). Optimal design of brushless AC exciter for large synchronous generators considering grid codes requirements. *IET Generation, Transmission & Distribution*, *12*(17), 3954-3962.

✉ Corresponding Author Email: *berat.altinok@isbirelektrik.com.tr*

A Scenario-Based Optimization Framework for End-of-Life Electric Vehicle Battery Recycling Network Design in Türkiye

Miraç Huzeyfe Güner✉, Bilal Ervural

Necmettin Erbakan University, Department of Industrial Engineering, Konya, Türkiye

Abstract

The continued diffusion of electric vehicles (EVs) will generate a significant but highly uncertain stream of end-of-life (EOL) lithium-ion batteries in the coming decades, making sustainable recycling and reverse logistics planning increasingly important [1], [2]. Recent studies have approached EOL EV battery recycling from different perspectives, including recycling policy frameworks [1], reverse logistics network design [2], resilient transfer-station site selection [3], location-adjustment under battery capacity and quantity uncertainty [4], and preprocessing facility location [5]. However, country-specific scenario-based optimization studies for emerging EV battery recycling networks remain limited, while the strategic siting problem is driven by long-term uncertainty in EV adoption, battery lifetime, and second-use rates [6]. This study proposes a scenario-based multi-period capacitated facility location framework for planning an EOL EV battery recycling network in Türkiye. The framework considers provincial demand zones, candidate inspection/preprocessing facilities, and candidate recycling facilities. Future battery waste quantities are estimated under alternative EV adoption, battery lifetime, and second-use scenarios. The objective minimizes total network cost, including facility establishment, collection, transportation, preprocessing, recycling, and external-processing or temporary-storage penalty costs, subject to flow-balance, facility-opening, and capacity constraints. The model is applied to a Türkiye case using province-level demand proxies and road-distance-based transportation costs. The computational study identifies facility configurations that remain stable across alternative demand scenarios and examines how second-use rates, battery lifetime assumptions, and demand growth affect the number, location, and capacity utilization of recycling facilities. The study contributes to the reverse logistics and facility location literature by developing a scenario-based optimization framework for the emerging EOL EV battery recycling problem in Türkiye and by providing decision support aligned with circular-economy and sustainable waste-management goals.

Keywords: Reverse logistics, facility location, end-of-life EV batteries, scenario-based optimization, demand uncertainty, mixed-integer programming

References

[1] Ali, A., Al Bahrani, M., Ahmed, S., Islam, M. T., Qadir, S. A., & Shahid, M. (2025). Sustainable recycling of end-of-life electric vehicle batteries: EV battery recycling frameworks in China and the USA. Recycling, 10(2), 68.

[2] Lygizos, A., Kastanaki, E., & Giannis, A. (2025). Designing a reverse logistics network for electric vehicle battery collection, remanufacturing, and recycling. Sustainability, 17(17), 7643.

[3] Feng, J., Guo, P., Xu, G., Xu, G., & Ning, Y. (2024). An integrated decision framework for resilient sustainable waste electric vehicle battery recycling transfer station site selection. Applied Energy, 373, 123897.

[4] Du, Y., Zhou, Y., Jia, D., & Li, X. (2024). The end-of-life power battery recycling & remanufacturing center location-adjustment problem considering battery capacity and quantity uncertainty. Journal of Environmental Management, 357, 120774.

[5] Haynes, M. W., Cáceres González, R., & Hatzell, M. C. (2024). Optimizing geographic locations for electric vehicle battery recycling preprocessing facilities in California. RSC Sustainability, 2(2), 377–389.

[6] Tadaros, M., Migdalas, A., Samuelsson, B., & Segerstedt, A. (2022). Location of facilities and network design for reverse logistics of lithium-ion batteries in Sweden. Operational Research, 22(2), 895–915.

✉ Corresponding Author Email: *mirachuzeyfeguner@gmail.com*

A Review of Parallel Radial Basis Function and Bayesian Methods for High-Dimensional Expensive Black-Box Optimization

Munarbek Aidaraliev✉, Rommel G. Regis

Saint Joseph's University, Department of Mathematics, Philadelphia, Pennsylvania, USA

Abstract

Many surrogate methods have been proposed for expensive black-box optimization. Among the most popular are Bayesian Optimization (BO) [1] and Radial Basis Function (RBF) methods [2]. To substantially reduce the wall-clock time to find an optimal solution or at least a good solution to a computationally expensive optimization problem, parallel surrogate algorithms have been developed that can take advantage of multi-core computers that are now ubiquitous. This study provides a review of parallel surrogate optimization methods, including parallel BO and RBF methods. Moreover, this paper compares the parallel performance of some widely used surrogate methods, including the DYCORS and the TuRBO algorithms on several engineering applications and well-known benchmark problems. DYCORS (DYnamic COordinate search using Response Surface models) [3] is an optimization method designed for high-dimensional expensive black-box functions that typically uses RBF surrogates. It dynamically narrows the search space via a form of dimension reduction as the computational budget runs out. TuRBO (Trust Region BO) [4] is designed to scale BO to high-dimensional problems by maintaining several localized probabilistic models and selects sample points using a trust region approach in conjunction with a multi-armed bandit strategy. Although BO and RBF methods are both popular, relatively limited comparisons have been made on their performance especially in parallel. Among the engineering applications considered include a 14-D robot pushing problem, and a 60-D rover trajectory planning problem, and a 72-D problem on the management of groundwater bioremediation. Additionally, the parallel algorithms are also tested on 200-D instances of some well-known benchmark problems.

Keywords: Surrogate optimization, parallel optimization, high-dimensional black-box optimization, radial basis function, Bayesian optimization

Acknowledgements

This study was supported by the Saint Joseph's University Summer Scholars Program.

References

[1] Garnett, R. (2023). Bayesian Optimization. Cambridge University Press.
[2] Regis, R. G., & Shoemaker, C. A. (2007). A stochastic radial basis function method for the global optimization of expensive functions. INFORMS Journal on Computing, 19(4), 497-509.
[3] Regis, R. G., & Shoemaker, C. A. (2013). Combining radial basis function surrogates and dynamic coordinate search in high-dimensional expensive black-box optimization. Engineering Optimization, 45(5), 529-555.
[4] Eriksson, D., Pearce, M., Gardner, J. R., Turner, R. D., & Poloczek, M. (2019). Scalable global optimization via local Bayesian optimization. In Advances in neural information processing systems (Vol. 32). Curran Associates, Inc.

✉ Corresponding Author Email: *munarbek.aidaraliev@sju.edu*

Optimal Placement of Photovoltaic, Electric Vehicle Charging Stations, and Battery Energy Storage Systems in Distribution Networks Using a Hybrid CHAO

Mehmet Çeçen✉

Selcuk University, Ilgin Vocational School, Electric and Energy Department, Konya, Türkiye

Abstract

The increasing integration of photovoltaic (PV) and electric vehicles charging stations (EVCS) systems into modern distribution networks is placing significant pressure on energy systems [1, 2]. Battery Energy Storage Systems (BESS) are one of the prominent solutions to address this problem and support the system. While considering the coordinated optimal placement of PV units and EVCS [3, 4], the coordinated inclusion of BESS as a third controllable component has not been sufficiently investigated in the literature [5]. This study proposes a comprehensive optimization framework for the simultaneous optimal placement and sizing of PV, EVCS, and BESS in an IEEE 33-bus radial distribution test system. Minimizing total active power losses and bus voltage deviation were chosen as objective functions. It is subject to bus voltage limits, DG capacity, EVCS power demand, and BESS operational constraints including charge/discharge efficiency and charge state limits [5, 6]. To solve this complex problem, a novel hybrid meta-heuristic algorithm, Coati Hunt with Adaptive Contrast-Based Learning Optimization (CHAO), has been introduced. CHAO extends the Coati Optimization Algorithm (COA) [7] for preserving population diversity, to avoid local optima, and to balance exploration and exploitation throughout the iterative process. The results show that the proposed CHAO algorithm achieves superior convergence behavior, lower active power losses and supports the sustainable integration of EV infrastructure into renewable energy-backed multi-energy systems.

Keywords: Battery energy storage system, photovoltaic, electric vehicle charging station, optimal allocation, CHAO algorithm, active power loss minimization.

References

[1] Mohamed, M. A. E., Gawish, A. N. A., & Metwally, M. E. (2026). Optimal electric vehicle charging stations and distributed generation placement by partitioning the distribution network using the modified newman fast algorithm. Scientific Reports, 16, Article 35433. https://doi.org/10.1038/s41598-026-35433-5

[2] Abdelwahab, S. A. M., et al. (2025). Stochastic carbon-aware planning of renewable DGs and EV charging stations with demand flexibility in smart urban grids. Scientific Reports, 15, Article 17504. https://doi.org/10.1038/s41598-025-17504-1

[3] Sahay, S., et al. (2025). Optimized placement of distributed generators, capacitors, and EV charging stations in reconfigured radial distribution networks using enhanced artificial hummingbird algorithm. Scientific Reports, 15, Article 11144. https://doi.org/10.1038/s41598-025-11144-x

[4] Prempeh, I., et al. (2025). Optimal allocation of distributed generation units and fast electric vehicle charging stations for sustainable cities. Green Energy and Intelligent Transportation, 4, Article 100281. https://doi.org/10.1016/j.geits.2025.100281

[5] Jaradat, T., & Khatib, T. (2025). Optimal sizing of battery energy storage system in electrical power distribution network. Energy Sources, Part A: Recovery, Utilization, and Environmental Effects, 47(1). https://doi.org/10.1177/01445987241300183

[6] Khunkitti, S., Pompern, N., Premrudeepreechacharn, S., & Siritaratiwat, A. (2024). Optimal placement and capacity of BESS and PV in EV integrated distribution systems: The Tenth Feeder of Phitsanulok Substation case study. Batteries, 10(6), Article 212. https://doi.org/10.3390/batteries10060212

[7] Dehghani, M., Montazeri, Z., Trojovská, E., & Trojovský, P. (2023). Coati optimization algorithm: A new bio-inspired metaheuristic algorithm for solving optimization problems. Knowledge-Based Systems, 259, Article 110011. https://doi.org/10.1016/j.knosys.2022.110011

✉ Corresponding Author Email: *mehmet.cecen@selcuk.edu.tr*

Hosoya Matrix Method for Linear Pantograph Differential Equations

Gözde Karapelit[1], Ali Konuralp[2]✉

[1] *Manisa Celal Bayar University, Institute of Graduate Education, Department of Mathematics, Manisa, Turkey*
[2] *Manisa Celal Bayar University, Faculty of Engineering and Natural Science, Department of Mathematics, Manisa, Turkey*

Abstract

A matrix collocation method based on Hosoya polynomials is developed to obtain approximate solutions of higher-order linear generalized pantograph differential equations under mixed conditions, including initial and/or boundary conditions. In this method, numerical solutions are found by means of the algebraic systems that are obtained using both equally spaced and Chebyshev-Lobatto collocation points, separately. Several example problems are considered to evaluate the applicability of the method and the procedure for choosing the collocation points.

Keywords: Hosoya Polynomials, Matrix Collocation Method, Hosoya Polynomial based Matrix Collocation Method

References

[1] David J. Evans and Kamal R. Raslan. The Adomian decomposition method for solving delay differential equation. International Journal of Computer Mathematics, 82(1):49–54, 2005.
[2] Liu, M. Z., & Li, D. (2004). Properties of analytic solution and numerical solution of multi-pantograph equation. Applied Mathematics and Computation, 155(3), 853-871.
[3] A. Konuralp and G. Hayta. On solution of differential equations by matrix method based on Freud polynomials. Master's thesis, Institute of Graduate Education, Manisa Celal Bayar University, Manisa, 2021.
[4] A. Konuralp and S. Öner. Numerical solutions based on a collocation method combined with Euler polynomials for linear fractional differential equations with delay. International Journal of Nonlinear Sciences and Numerical Simulation, 21(6):539–547, 2020.
[5] A. Konuralp and G. Karapelit. Hosoya polynomial based matrix method for higher order linear generalized pantograph differential equations, Master's thesis, Institute of Graduate Education, Manisa Celal Bayar University, Manisa, 2025
[6] Mundewadi, R.A., Jummannaver, R.B. Hosoya polynomial method for the numerical solution of Volterra integral equations. *J.Umm Al-Qura Univ. Appll. Sci.* 11, 829–845 (2025). https://doi.org/10.1007/s43994-024-00191-5.

✉ Corresponding Author Email: *ali.konuralp@cbu.edu.tr*

High-Dimensional Expensive Black-Box Constraint Satisfaction and Optimization Using Surrogate-Assisted Evolutionary Algorithms

Rommel G. Regis✉

Saint Joseph's University, Department of Mathematics, Philadelphia, Pennsylvania, USA

Abstract

Finding feasible solutions for high-dimensional constrained optimization problems can be challenging especially when the objective and constraint functions are black-box and computationally expensive. This paper presents a multi-objective approach for the continuous constraint satisfaction problem (CCSP) that can be used with a generic evolutionary algorithm. When searching for a feasible solution, the idea is to perform a nondominated sort of the current parent population and offspring using multiple constraint violation measures to determine the set of parents for the next generation. This strategy is used to developed a two-phase evolutionary programming (EP) algorithm for constrained optimization where the first phase solves the CCSP, yielding feasible solutions, which are then improved during the second phase. Furthermore, the proposed CCSP strategy is used to developed a surrogate-assisted two-phase EP for high-dimensional expensive constrained black-box optimization. This new method extends a previous surrogate-assisted constrained EP that requires a feasible initial solution [1]. The proposed two-phase EP and its version assisted by radial basis function (RBF) surrogates are compared with other evolutionary approaches such as SDECOA [2] and CMODE [3] on well-known test problems and on the MOPTA08 benchmark from the auto industry with 124 decision variables and 68 black-box inequality constraints [4]. The proposed RBF-assisted two-phase EP generally requires fewer function evaluations to find feasible solutions compared to SDECOA, CMODE and the two-phase EP without surrogates on the problems considered. Moreover, it performs much better the alternative methods in terms of the penalized objective function value when the computational budget is relatively limited.

Keywords: Constraint satisfaction, constrained optimization, high-dimensional black-box optimization, evolutionary programming, surrogate model, radial basis functions

References

[1] Regis, R. G. (2014). Evolutionary programming for high-dimensional constrained expensive black-box optimization using radial basis functions. IEEE Transactions on Evolutionary Computation, 18(3), 326-343.

[2] Zhu, L., Zhou, G., Zhou, Y., Luo, Q., Huang, H., & Wei, X. (2025). Self-adaptive differential evolution-based coati optimization algorithm for multi-robot path planning. Robotica, 43(3), 959–996.

[3] Wang, Y., & Cai, Z. (2012). Combining multiobjective optimization with differential evolution to solve constrained optimization problems. IEEE Transactions on Evolutionary Computation, 16(1), 117-134.

[4] Jones, D. R. (2008). Large-scale multi-disciplinary mass optimization in the auto industry [Conference presentation]. Modeling and Optimization: Theory and Applications (MOPTA) 2008 Conference, Ontario, Canada.

✉ Corresponding Author Email: *rregis@sju.edu*

Approximate Controllability of Ψ-Hilfer Fractional Stochastic Differential Systems of Order $1 < \mu < 2$

Ahmad Faraz Razi ✉, Javid Ali

Aligarh Muslim University, Department of Mathematics, Aligarh, India

Abstract

This paper investigates the approximate controllability of a class of nonlinear Ψ- Hilfer fractional stochastic differential systems of order $1 < \mu < 2$ in separable Hilbert spaces. The motivation of this study is the emerging necessity to model and control complex real-world phenomena which are influenced by stochastic effects and exhibits long range memory. The Ψ- Hilfer fractional derivative, which generalises both the Riemann-Liouville and Caputo derivatives through an arbitrary kernel function Ψ offers a highly flexible framework for capturing memory effects and hereditary properties in complex dynamical systems subject to stochastic perturbations. The existence of mild solutions is established by employing the Schauder fixed point theorem together with the measure of noncompactness and the Arzela-Ascoli theorem. Subsequently, sufficient conditions based on the approximate controllability of the nonlinear system are obtained, assuming that the associated linear system is approximately controllable. The flexibility of the Ψ-Hilfer operator allows our results to simultaneously recover and extend several known controllability results for special choices of Ψ. Moreover, to demonstrate the applicability of the theoretical findings, a Ψ-Hilfer fractional stochastic partial differential equation subject to Dirichlet boundary conditions is examined.

Keywords: Approximate controllability; Ψ-Hilfer fractional derivative; stochastic differential equations; mild solution; measure of noncompactness; cosine family; fixed point theorem.

Acknowledgements

Acknowledgements may be made to those individuals or institutions not mentioned elsewhere in the paper that made an important contribution.

References

[1] Podlubny, I. (1999). Fractional differential equations: An introduction to fractional derivatives, fractional differential equations, to methods of their solution and some of their applications. Academic Press, San Diego.
[2] Liang, J., Mu, Y., & Xiao, T.J. (2025). Evolution Ψ-Hilfer fractional differential equations in Banach spaces. Electronic Journal of Differential Equations, 2025(109), 1–17.
[3] Mainardi, F. (2010). Fractional calculus and waves in linear viscoelasticity. Imperial College Press, London.
[4] Kilbas, A.A., Srivastava, H.M., & Trujillo, J.J. (2006). Theory and applications of fractional differential equations. Elsevier, Amsterdam.
[5] Sakthivel, R., Suganya, S., & Anthoni, S.M. (2012). Approximate controllability of fractional stochastic evolution equations. Computers and Mathematics with Applications, 63(3), 660–668.
[6] Dhayal, R., Malik, M., & Abbas, S. (2021). Approximate controllability for a class of non-instantaneous impulsive stochastic fractional differential equations driven by fractional Brownian motion. Differential Equations and Dynamical Systems, 29(1), 175–191.

✉ Corresponding Author Email: *javid.mm@amu.ac.in*

Multi-Layered Artificial Intelligence and Robotic Process Automation in Supply Chain Management

Melissa Bilge Karadere✉, Kutay Pekşen, Deniz İlaslan, Zehra Kamışlı Öztürk

Eskişehir Technical University, Department of Industrial Engineering, Eskişehir, Türkiye

Abstract

This study addresses structural barriers to data-driven decision-making in supply chain operations and proposes an integrated framework combining artificial intelligence, robotic process automation (RPA), and large language models within a multi-layered architecture [1], [2]. Conducted based on the operational needs of Eczacıbaşı VitrA Karo, the framework is adaptable to organizations with similar process structures. The main problem is not the absence of data, but the inability to use existing data at the right time and for the right decision. High-volume data flows, fragmented information sources across SAP/ERP modules, and interdepartmental information gaps create inefficiencies in critical supply chain activities [1]. To address this, existing processes were analyzed using process mining and BPMN 2.0 to identify bottlenecks and automation opportunities [3]. Five processes—idle stock management, transportation cost parameter tracking, subcontracted production delay detection, unconfirmed order analysis, and freight reconciliation—were automated through RPA [2], resulting in a saving of 80 man-hours per week. In the artificial intelligence layer, department-specific agents were developed. For Purchasing, time series models forecasted diesel fuel prices, electricity market prices, and exchange rates using historical data and walk-forward validation [4]. For External Supply, a risk classification model was applied to subcontracted stock records while addressing class imbalance and data leakage. For Production Planning, the product portfolio was segmented into risk groups based on sales performance and production capacity. Agent outputs are interpreted by a large language model and transformed into plain-language decision recommendations for daily workflows. A shared coordination layer connects these outputs with ERP/SAP and RPA processes, creating a closed loop in which decisions are generated, implemented, and communicated within the same architecture. The study contributes by integrating AI, RPA, and language-model-based decision support in a real industrial supply chain setting, addressing a literature gap where these technologies are mostly examined separately [1], [2].

Keywords: Robotic Process Automation, Time Series Forecasting, Machine Learning, Supply Chain Management, Process Mining

Acknowledgements

This study was supported by Eskişehir Technical University Scientific Research Projects Commission (BAP).

References

[1] Toorajipour, R., Sohrabpour, V., Nazarpour, A., Oghazi, P., & Fischl, M. (2021). Artificial intelligence in supply chain management: A systematic literature review. Journal of Business Research, 122, 502–517.

[2] Nielsen, I. E., Piyatilake, A., Thibbotuwawa, A., Silva, M. M. D., Bocewicz, G., & Banaszak, Z. A. (2023). Benefits realization of robotic process automation (RPA) initiatives in supply chains. IEEE Access, 11, 37623–37636. doi: 10.1109/ACCESS.2023.3266293

[3] van der Aalst, W. M. P. (2016). Process Mining: Data Science in Action. Springer Berlin, Heidelberg. doi: 10.1007/978-3-662-49851-4

[4] Hyndman, R. J., & Athanasopoulos, G. (2021). Forecasting: Principles and Practice (3rd ed.). OTexts, Melbourne, Australia.

✉ Corresponding Author Email: *mbkmelissa@gmail.com*

Experimental Analysis of the Thermal Performance Effects of Enclosure Roof Geometry in Dry-Type Transformers

Ramazan Altay[1]✉, Gülşen Yaman[2]

[1] *Ra İleri Mühendislik Hizmetleri San. ve Tic. Ltd. Şti, BAUN Teknokent, Balıkesir, Türkiye*
[2] *Balıkesir University Mechanical Engineering, Balıkesir, Türkiye*

Abstract

Transformers are fundamental equipment in meeting global energy demands, and their production volume has increased significantly in recent years. Although these machines operate with approximately 99% efficiency, even a 1% loss can lead to considerable thermal issues. Therefore, thermal management must be regarded as a critical parameter in transformer design.

Dry-type transformers are increasingly preferred in the market due to their non-flammable nature, enhanced safety, and environmentally friendly characteristics. In cabinet-free dry-type transformers, heat dissipation in ventilated environments can be easily estimated using empirical formulas. However, in cabinet-enclosed dry-type transformers, additional flow resistances arise due to air inlet–outlet openings and cabinet geometry, leading to higher temperature levels. Among these factors, the geometry of the cabinet roof plays a particularly significant role.

In this study, the effects of three different cabinet roof geometries on the temperature distribution of dry-type transformers were experimentally investigated and compared with numerical analyses. The findings indicate that, in terms of cabinet surface temperatures, the lowest value was obtained with the C-type roof at 29.1 °C, while the highest was observed with the A-type roof at 33.3 °C. Regarding coil temperatures, the lowest value was measured with the B-type roof at 75.3 °C, whereas the highest was recorded with the C-type roof at 81.3 °C. These results clearly demonstrate that cabinet roof geometry has a decisive impact on both cabinet surfaces and coil temperatures. For instance, while the C-type roof yielded the best outcome for cabinet surfaces, it produced the most unfavorable result for coil temperatures.

Overall, the findings confirm that the distribution of air flow and temperature inside the cabinet is directly related to roof geometry, thereby contributing to the development of optimized cabinet designs.

Keywords: Dry-type transformer, Thermal management, Cabinet roof geometry, Experimental analysis, Temperature distribution

Acknowledgements

This work has received funding from the T.C. Energy Market Regulatory Authority (EPDK) Research and Development Project "Over 400 kVA Pole-Type Transformer Design and Manufacturing", under grant agreement No. 241025.

References

[1] Yaman, G., Altay, R., & Yaman, R. (2019). Validation of computational fluid dynamic analysis of natural convection conditions for a resin dry-type transformer with a cabin. Thermal Science, 23(Suppl. 1), 23–32. https://doi.org/10.2298/TSCI180919327Y

[2] Adışen, C., Hazar, İ., Gökhan Demir, V., & Altay, R. (2024, June 26). Numerical analysis of porosity values for different IP classes and verification with experimental studies. The 3rd International Conference on Applied Mathematics in Engineering (ICAME'24). https://icame.balikesir.edu.tr/documents/ICAME24_AbstractsBook.pdf#page=215

[3] Wei Wu, Yong Wang, Zepu Wang (2019). CFD Simulation on Heat Exchanger Cooled Dry-type Transformers. 2nd World Congress on Electrical Engineering and Computer Systems and Science (EECSS'16). https://doi.org/10.11159/eee16.143

✉ Corresponding Author Email: *ramazan.altay@ra-engineer.com*

Assessment of Spatial Accessibility and Wayfinding Performance in University Campuses: A Case Study of Atlas University Vadi Campus

Recep Duranay[1]✉, Beyza Çermikli[2], Elif Tarakçı[3]

[1] *Istanbul Atlas University, Computer Engineering Department, Istanbul, Turkey*
[2] *Istanbul Atlas University, Interior Architecture and Environmental Design, Istanbul, Turkey*
[3] *Istanbul Atlas University, Industrial Engineering Department, Istanbul, Turkey*

Abstract

University campuses are complex spatial systems where social, cultural, and recreational activities take place in addition to educational and research functions. The spatial organization and level of accessibility of campuses directly affect users' wayfinding performance and spatial experiences. The aim of this study is to evaluate the main and secondary entrance points of Atlas University Vadi Campus, located in Kağıthane, Istanbul, in terms of access networks, spatial organization, and functionality. Within this scope, a data-driven evaluation framework has been developed to reduce wayfinding uncertainty by analyzing the campus's spatial hierarchy and user movements.

According to Lynch, spatial legibility is shaped through paths, edges, districts, nodes, and landmarks, and influences individuals' wayfinding capacity (1). However, since this approach remains limited in explaining the structural characteristics of spatial organization, the present study addresses spatial legibility on a configurational basis using the Space Syntax method.

In the first stage, the campus layout was analyzed using the Space Syntax method; integration, connectivity, and control values were calculated to determine the spatial hierarchy and potential movement axes. This method, which examines the relationships between spatial structure and social interaction, evaluates connections between spaces through quantitative and graphical measures (2). In the second stage, user movements were modeled using the Markov Chain approach, densities at entrance points were evaluated through Queueing Theory, and different usage scenarios were tested using Monte Carlo simulations. In addition, the Fuzzy TOPSIS method was employed to determine the effects of environmental factors on user comfort. (3)

As a result of the holistic evaluation of the obtained data, the relationships between highly integrated spatial axes and user movement densities were identified. The analyses enabled the determination of highly accessible areas and critical nodes directing movement flows, demonstrating that circulation clarity, accessibility, and spatial legibility directly influence the campus experience (4). The study identified areas that remain weak in terms of accessibility and proposed improvements for pedestrian circulation and wayfinding systems. It is expected that this research will contribute to the evaluation of accessibility, spatial organization, and wayfinding relationships on university campuses and provide guidance for future campus planning studies.

Keywords: Campus Design, Queueing Theory, Process Optimization, Markov Chain, Monte Carlo Simulation, Spatial Legibility

References

[1] Lynch, K. (1960). The Image of the City. Cambridge, MA: MIT Press.
[2] Hillier, B., & Hanson, J. (1984). The social logic of space. Cambridge University Press.
[3] Biderci, H., & Canbaz, B. (2019). Ergonomic Room Selection with Intuitive Fuzzy TOPSIS Method. *Journal of Polytechnic*, 22(4), 1085-1094.
[4] Zencirkıran, A., & Şuta, O. (2025). Spatial organization and user experience in a university campus: A mixed-method Space Syntax analysis of Trakya University Balkan Campus. Sustainability, 17(24), 1-35.

✉ Corresponding Author Email: *recep.duranay@atlas.edu.tr*

Energy Optimization in Paper Manufacturing

Sadettin Durmuş Talipoğlu

Kocaeli University, Electronics Engineering Department, Kocaeli, Turkey

Abstract

In paper manufacturing plants, electricity and steam are tightly coupled energy carriers, where electricity is generated by gas turbines and the resulting steam is directly used in critical processes such as paper drying. Since steam production itself requires additional energy input, the efficient coordination of electricity and steam generation is essential to minimize fuel consumption, reduce operational costs, and improve overall process efficiency. In large-scale industrial campuses, this interdependent structure makes energy management a complex optimization problem, as both electricity and steam demands must be satisfied simultaneously under varying operating conditions. In conventional practice, operational decisions are often made manually based on operator experience. However, such approaches may lead to suboptimal operating conditions, resulting in excessive natural gas consumption and consequently higher carbon emissions and environmental impact. In this study, a real-world energy optimization system is developed for an industrial campus, where the objective is to minimize total operational cost while meeting both electricity and steam requirements. The system first estimates fuel consumption and steam production characteristics of gas turbines using machine learning models trained on historical operational data. Based on the predicted electricity generation, the required steam production from boiler units is determined, and a comprehensive cost function is formulated. An optimization framework is then applied to determine the optimal production distribution that minimizes total fuel cost under system constraints. Unlike traditional operation, the proposed approach integrates machine learning and optimization to provide a data-driven decision mechanism. The results demonstrate that the system improves operational efficiency, supports more efficient steam utilization in paper production, and achieves up to 5% reduction in energy generation costs, while also contributing to reduced fuel consumption and lower environmental impact.

Keywords: Gas turbines, Electric production, Tissue paper production; optimization; machine learning.

References

[1] Yu, B., Liu, W., Xie, D., Cui, X., & Zhang, H. (2025). A novel gas turbine performance prediction model incorporating the residual connection and feature engineering methods. Energy, 332, 137251.

[2] Alsultan, A. M. T., Bani, N. A., Muhtazaruddin, M. N., Muhammad-Sukki, F., Usman, S., Ahmad, N., Kamarudin, M. K. A., & Zulkipli, M. (2026). Optimization strategies in residential energy management systems: A comprehensive review. *International Journal of Energy Research, 2026*(1), 6685065. https://doi.org/10.1155/er/6685065

[3] Liu, Z., & Karimi, I. A. (2020). Gas turbine performance prediction via machine learning. Energy, 192, 116627.

[4] Kleimaier, A., & Schroder, D. (2000). Optimization strategy for design and control of a hybrid vehicle. In Proceedings of the 6th International Workshop on Advanced Motion Control (pp. 459–464).

[5] Tan, W., Liu, X., Song, F., Wang, D., Huo, Z., Yao, Z., Han, Y., & Zhang, X. (2026). Optimization of a gas–steam–power system linked with energy storage devices in steel enterprises. Case Studies in Thermal Engineering, 80, 107889.

[6] Hilgers, M. (2023). Fuel consumption and consumption optimization (2nd ed.). Springer Vieweg. https://doi.org/10.1007/978-3-662-66449-0

✉ Corresponding Author Email: *sdurmustalipoglu@gmail.com*

Asymptotically Unpredictable Solutions of Quasilinear Systems with Delay

Fatma Tokmak Fen[1]✉, Mehmet Onur Fen[2]

[1] *Gazi University, Department of Mathematics, Ankara, Türkiye*
[2] *TED University, Department of Mathematics, Ankara, Türkiye*

Abstract

In this study we rigorously prove the existence and uniqueness of asymptotically unpredictable solutions of quasilinear systems with delay. Such motions are capable of producing sensitive dependence on initial conditions in a dynamics, which is one of the most important factors that plays a role in the emergence of chaos. The presence of asymptotically unpredictable functions which are not unpredictable approves the novelty of the results. The Banach fixed point theorem and equivalent integral equations are utilized to obtain the main results. Appropriate simulations, which support the theory, are also provided.

Keywords: Systems with delay, Asymptotic unpredictability, Sensitive dependence on initial conditions

References

[1] Fen, M.O., & Tokmak Fen, F. (2025). Continuous-Time and Discrete-Time Quasilinear Systems with Asymptotically Unpredictable Solutions. Mediterranean Journal of Mathematics, 22, 168.
[2] Fen, M.O., & Tokmak Fen, F. (2024). Asymptotically unpredictable trajectories in semiflows. Communications in Nonlinear Science and Numerical Simulation, 134, 108029.
[3] Akhmet, M., & Fen, M.O. (2018). Non-autonomous equations with unpredictable solutions. Communications in Nonlinear Science and Numerical Simulation, 59, 657–670.
[4] Fink, A.M. (1974). Almost Periodic Differential Equations. Springer, Berlin.
[5] Sell, G.R. (1971). Topological Dynamics and Ordinary Differential Equations. Van Nostrand Reinhold Company, London.
[6] Shcherbakov, B.A. (1969). Poisson stable solutions of differential equations, and topological dynamics. Differentsial'nye Uravneniya, 5, 2144–2155. (in Russian)
[7] Driver, R.D. (1977). Ordinary and Delay Differential Equations. Springer, New York.

✉ Corresponding Author Email: *fatmatokmak@gazi.edu.tr*

A New Kind of Motion in Semiflows: Asymptotically Unpredictable

Mehmet Onur Fen[1]✉, Fatma Tokmak Fen[2]

[1] *TED University, Department of Mathematics, Ankara, Türkiye*
[2] *Gazi University, Department of Mathematics, Ankara, Türkiye*

Abstract

This study is concerned with a new kind of motion, called asymptotically unpredictable, in semiflows. We demostrate that such motions lead to sensitive dependence on initial conditions in the dynamics. This feature is similiar to the one of unpredictable motions, but the novelty is the approvement under a weaker hypothesis. We also show that the set of continuous asymptotically unpredictable functions defined on the real axis properly includes the set of unpredictable ones. An application to differential equations is also provided.

Keywords: Semiflows, Asymptotic unpredictability, Differential equations

References

[1] Fen, M.O., & Tokmak Fen, F. (2024). Asymptotically unpredictable trajectories in semiflows. Communications in Nonlinear Science and Numerical Simulation, 134, 108029.
[2] Akhmet M., & Fen M.O. (2016). Unpredictable points and chaos. Communications in Nonlinear Science and Numerical Simulation, 40, 1–5.
[3] Devaney, R.L. (1989). An introduction to chaotic dynamical systems. United States of America: Addison-Wesley.
[4] Cheban, D.N. (1977). Solutions of operator equations that are asymptotically stable in the sense of Poisson. Differentsial'nye Uravneniya, 13 1411–1417 (in Russian).
[5] Sell, G.R. (1971). Topological Dynamics and Ordinary Differential Equations. Van Nostrand Reinhold Company, London.
[6] Shcherbakov, B.A. (1969). Poisson stable solutions of differential equations, and topological dynamics. Differentsial'nye Uravneniya, 5, 2144–2155. (in Russian)
[7] Nemytskii V.V., & Stepanov V.V. (1960). Qualitative theory of differential equations. Princeton University Press, Princeton, New Jersey.

✉ Corresponding Author Email: *onur.fen@tedu.edu.tr*

Modelling of Geothermal Gradient Distribution in the Balıkesir Region via Physics-Informed Neural Networks (PINNs)

Sevdanur Genç ✉

Balikesir University, Department of Computer Engineering, Balikesir, Turkey

Abstract

In this study, the subsurface thermal structure of the Balıkesir region (38.5°–40.38°N, 26.15°–29.0°E) was modeled using physics-informed neural networks (PINNs), utilizing geothermal gradient and heat flow measurements from 62 observation points compiled from the IHFC 2024 database. The model integrates a partial differential equation (PDE) constraint derived from the diffusion equation with a learnable smoothness parameter, and captures spatial irregularities through Fourier embedding. A single train/validation split yielded a validation Mean Absolute Error (Val MAE) of 10.64 °C/km and a validation Root Mean Square Error (Val RMSE) of 11.56 °C/km; furthermore, a 5-fold cross-validation resulted in a PINN CV MAE of 13.90 ± 2.08 °C/km. This performance demonstrates a distinct superiority when compared to Radial Basis Function (RBF) interpolation (15.32 ± 2.90 °C/km) and the constant-mean baseline (15.17 °C/km). Denizköy (130.47 °C/km), Babadere1 (100.0 °C/km), and Selimiye (97.65 °C/km) were identified as the regions exhibiting the highest thermal anomalies. The findings indicate that the PINN approach provides a robust and physically consistent framework for geothermal mapping under sparse data conditions.

Keywords: Geothermal gradient, Physics-Informed Neural Networks, Balıkesir, IHFC 2024, Heat flow, Deep learning

References

[1] Cueto-Felgueroso, L., & Peraire, J. (2008). A time-adaptive finite volume method for the Cahn-Hilliard and Kuramoto-Sivashinsky equations. Journal of Computational Physics, 227(24), 9985–10017.
[2] IHFC (2024). International Heat Flow Commission Global Heat Flow Database 2024. International Heat Flow Commission. https://ihfc-iugg.org/products/global-heat-flow-database/
[3] Jagtap, A. D., & Karniadakis, G. E. (2020). Extended physics-informed neural networks (XPINNs): A generalized space-time domain decomposition based deep learning framework for nonlinear partial differential equations. Communications in Computational Physics, 28(5), 2002–2041.
[4] Karniadakis, G. E., Kevrekidis, I. G., Lu, L., Perdikaris, P., Wang, S., & Yang, L. (2021). Physics-informed machine learning. Nature Reviews Physics, 3(6), 422–440. https://doi.org/10.1038/s42254-021-00314-5
[5] Pollack, H. N., Hurter, S. J., & Johnson, J. R. (1993). Heat flow from the Earth's interior: Analysis of the global data set. Reviews of Geophysics, 31(3), 267–280. https://doi.org/10.1029/93RG01249
[6] Raissi, M., Perdikaris, P., & Karniadakis, G. E. (2019). Physics-informed neural networks: A deep learning framework for solving forward and inverse problems involving nonlinear partial differential equations. Journal of Computational Physics, 378, 686–707. https://doi.org/10.1016/j.jcp.2018.10.045
[7] Tancik, M., Srinivasan, P., Mildenhall, B., Fridovich-Keil, S., Raghavan, N., Singhal, U., Ramamoorthi, R., Barron, J. T., & Ng, R. (2020). Fourier features let networks learn high frequency functions in low dimensional domains. Advances in Neural Information Processing Systems, 33, 7537–7547.
[8] Wang, S., Teng, Y., & Perdikaris, P. (2021). Understanding and mitigating gradient flow pathologies in physics-informed neural networks. SIAM Journal on Scientific Computing, 43(5), A3055–A3081.

✉ Corresponding Author Email: *sevdanur.genc@balikesir.edu.tr*

Priority-Driven Portfolio Optimization of Interacting Energy Efficiency Measures: A Multi-Mode MILP Framework with Exact Interaction Modelling

Halil Sinoplugil[1]✉, Gülşen Yaman[2]

[1] *Balikesir University, Institute of Science and Technology, Mech. Eng. Dep, Balikesir, Turkiye*
[2] *Balikesir University, Mechanical Engineering Department, Balikesir, Turkiye*

Abstract

In building energy audits, efficiency measures are usually assessed in isolation and selected only after being ranked and pre-screened against a single criterion such as simple payback period [1]. This approach both neglects the physical interactions between measures and assumes that one criterion suffices for every decision-maker; yet a measure may offer a high net present value (NPV) while paying back slowly, whereas another may markedly improve efficiency at a high initial cost. This study develops a MATLAB-based, multi-mode Mixed-Integer Linear Programming (MILP) portfolio-optimization framework that integrates the results of multi-category energy audits (building-envelope insulation, windows/frames, flue-gas analysis, piping insulation, pump/motor systems, LED lighting, and renewable energy) conducted on a demonstrative educational building [2]. To eliminate double counting across measures, an interaction hierarchy is defined among demand-reducing, system-efficiency, and on-site substitution measures; the savings of system-efficiency measures are scaled by the residual demand left after concurrently selected demand-reducing measures, and this dependency is represented exactly through McCormick-based linearization. Around a common constraint core (legal limits, budget, payback threshold, economic life, and logical selection), the framework employs a switchable objective function to solve four scenarios simultaneously—NPV maximization, payback-period minimization, efficiency-gain maximization, and the best budget-compliant scenario—presenting them as a comparative panorama [3]. All combinations are searched globally without pre-screening, eliminating the local-optimum risk of ranking-based methods. The demonstrative application shows that, rather than imposing a single solution, the framework reveals the optimal portfolios corresponding to differing decision-maker priorities and offers a method generalizable to similar buildings.

Keywords: Energy efficiency measures, Mixed-integer linear programming (MILP), Portfolio optimization, Decision support system, Building energy retrofit

References

[1] Karbasforoushha, M.A., Khajehzadeh, M., Jearsiripongkul, T., Keawsawasvong, S., & Eslami, M. (2024). A comprehensive review of building energy optimization using metaheuristic algorithms. Journal of Building Engineering, 98, 111377

[2] Movlyanov, A., Akyol, B., & Selçuklu, S.B. (2024). Energy Planning and Optimization Model for Campus Buildings: A Case Study of Erciyes University. Journal of Architectural Sciences and Applications, 9(2), 1095–1116

[3] Rastegarpour, S., & Ferrarini, L. (2022). Energy Management in Buildings: Lessons Learnt for Modeling and Advanced Control Design. Frontiers in Energy Research, 10, 899866

✉ Corresponding Author Email: *halil.sinoplugil@balikesir.edu.tr*

Bridging Classical Solvers and Learned Operators: A JAX Framework for Hybrid Forward and Inverse Problems

Gabriel Torregrosa-Cortés✉, Daniel Santos-Oliván, Alejando Torres-Sánchez

European Molecular Biology Laboratory (EMBL), Barcelona, Spain

Abstract

Forward and inverse problems are central to biophysics: predicting observable signals from physical parameters and recovering those parameters from noisy, incomplete measurements. Classical methods provide physical consistency and interpretability but struggle with ill-posedness and expensive forward models. The adjoint method [4,5] enables efficient gradient computation but requires hand-derived equations and is tightly coupled to a specific model. Learned methods—including physics-informed neural networks (PINNs) [1], neural operators [2,3], and neural ODEs [6]—learn directly from data but may violate physical constraints and generalize poorly. Neither approach alone is sufficient.

I introduce a JAX-based package that unifies classical and learned methods through differentiable programming. Using JAX's automatic differentiation, it replaces hand-derived adjoints with end-to-end differentiable forward models, allowing classical methods and neural components to share a single computational graph. This enables hybrid workflows where learned models accelerate simulations while differentiable physics constrains and refines them.

Biophysical case studies demonstrate improved reconstruction quality, robustness to distribution shift, and computational efficiency while preserving physical consistency. Although motivated by biophysics, the framework is readily applicable to other physics-governed inverse problems, including geophysics and medical imaging.

Keywords: Inverse problems, machine learning, PINNs, differential equations

Acknowledgements: This work has been elaborated with the support of the EIPOC-Link fellowship.

References

[1] Raissi, M., Perdikaris, P., & Karniadakis, G. E. (2019). Physics-informed neural networks: A deep learning framework for solving forward and inverse problems involving nonlinear partial differential equations. *J. Comput. Phys.*, 378, 686–707.

[2] Lu, L., Jin, P., Pang, G., Zhang, Z., & Karniadakis, G. E. (2021). Learning nonlinear operators via DeepONet. *Nat. Mach. Intell.*, 3, 218–229.

[3] Li, Z., et al. (2021). Fourier neural operator for parametric partial differential equations. *ICLR*.

[4] Plessix, R.-E. (2006). A review of the adjoint-state method for computing the gradient of a functional with geophysical applications. *Geophys. J. Int.*, 167(2), 495–503.

[5] Tarantola, A. (2005). *Inverse Problem Theory and Methods for Model Parameter Estimation*. SIAM.

[6] Chen, R. T. Q., Rubanova, Y., Bettencourt, J., & Duvenaud, D. (2018). Neural ordinary differential equations. *NeurIPS*, 31.

✉ Corresponding Author Email: gabriel.toregrosa@embl.es

Mathematical Modelling of the Photoluminescence Behavior of a Carbazole-Based Schiff Base Compound and Examination from the Perspective of DFT Analysis and Sustainable Material Design

Ümit Çalışır [1]✉, Baki Çiçek[2]

[1] *Siirt University, Science and Technology Application and Research Center, Siirt, Türkiye*
[2] *Balıkesir University, Faculty of Sciences and Letters, Chemistry Department, Balıkesir, Türkiye*

Abstract

Organic semiconductor materials constitute a significant research area in next-generation optoelectronic applications due to their low energy consumption, high efficiency, and suitability for flexible device technologies [1,2]. In this study, the optical properties of a carbazole-based Schiff base compound synthesized by the condensation reaction between 3,6-diamino-N-hexylcarbazole and β-hydroxy-α-naphthaldehyde [3] were investigated using a holistic method combining experimental and theoretical approaches. Structural characterization of the compound was performed using FT-IR, H-NMR, C-NMR, LC-MS, and elemental analysis techniques. To gain a detailed understanding of the photoluminescence (PL) behavior, emission spectra obtained at different temperatures and excitation powers were evaluated using mathematical modelling methods. A multiple Gaussian deconvolution approach was applied to separate the emission bands, aiming to identify the underlying emission centers of the spectral structure. Furthermore, temperature-dependent PL data were analyzed using Arrhenius-type mathematical models to calculate the kinetic parameters related to non-radiative transition processes. Density functional theory (DFT) calculations, performed to theoretically support experimental photoluminescence findings, have allowed for a comprehensive evaluation of the relationship between the electronic structure and optical properties of the material. The study also addresses the issue of sustainable material development, discussing the potential of high-efficiency synthesis methods and DFT-supported design strategies to reduce experimental resource consumption and thus lower the carbon footprint. The results are expected to contribute to the development of next-generation organic light-emitting materials for OLED and other optoelectronic applications.

Keywords: Photoluminescence, Mathematical Modelling, Density Functional Theory (DFT), Gaussian Deconvolution, Carbon Footprint, Sustainable Material Design, OLED.

References

[1] Agarwal, N., Nayak, P. K., Ali, F., Patankar, M. P., Narasimhan, K. L., & Periasamy, N. (2011). Tuning of HOMO levels of carbazole derivatives : New molecules for blue OLED. Synthetic Metals, 161(5–6), 466–473. https://doi.org/10.1016/j.synthmet.2011.01.001

[2] Grigalevicius, S., Tavgeniene, D., Krucaite, G., Blazevicius, D., Griniene, R., Lai, Y.-N., Chiu, H.-H., & Chang, C.-H. (2018). Efficient blue and green phosphorescent OLEDs with host material containing electronically isolated carbazolyl fragments. Optical Materials, 79, 446–449. https://doi.org/https://doi.org/10.1016/j.optmat.2018.04.018

[3] Çiçek, B., Çalışır, Ü., Tavaslı, M., Tülek, R., & Teke, A. (2018). Synthesis and optical characterization of novel carbazole Schiff bases. Journal of Molecular Structure, 1153, 42–47. https://doi.org/10.1016/j.molstruc.2017.09.109

✉ Corresponding Author Email: *bcicek@balikesir.edu.tr*

MobileViTv2 Model Based- Fractional Gastrointestinal Endoscopy Images of Computer Vision Systems per Chaotic Learning Rate Scheduling

Berkay Emin[1], Yusuf Alaca[2], Yeliz Karaca[3]✉, Akif Akgül[2]

[1] *Department of Electronics and Automation, Hitit University, 19500 Çorum, Türkiye*
[2] *Department of Computer Engineering, Faculty of Engineering, Hitit University, 19030 Çorum, Türkiye*
[3] *Department of Mathematics and Department of Neurology, University of Massachusetts (UMass) Chan Medical School, Worcester, MA 01655, USA*

Abstract

Dynamic training strategy pertaining to chaotic learning rate signifies a mechanism by which learning rate fluctuates using non-periodic mathematical functions rather than tracking a fixed decay schedule for injecting controlled randomness into gradient descent process. MobileViTv2 is a lightweight computer vision model for high-performance Vision Transformers (ViTs) with resource-constrained mobile devices improving original MobileViT by introducing a separable self-attention mechanism, which reduces computational complexity [1]. ViTs are tailored for endoscopic image analysis by capturing long-range contextual data for reliable classification and lesion awareness. In endoscopic images, interclass visual similarity, illumination variations, tissue diversity and sample size require deep learning (DL) models to yield high classification accuracy with stable learning process [2]. Integrating fractional-order calculus and chaotic learning rate scheduling (CLRS) into DL models produces improvement in automated diagnostic precision for complex nonlinear conditions. When artificial intelligence (AI) algorithms are applied to interpret images instantaneously. Accordingly, this study addresses AI-based classification of gastrointestinal endoscopy images using Hyper Kvasir multi-modal dataset. Logistic map-based CLRS was compared with conventional cosine annealing approach. Evaluation results show logistic map-based CLRS improves classification, particularly in compact MobileViTv2 variants. In MViTv2-0.5 model, accuracy obtained with cosine annealing was 97.27%, whereas accuracy increased to 97.66% with logistic map-based CLRS. Macro-F1 score increased from 97.02% to 97.29%, while AUC value reached 0.9984 from 0.9983, indicating that CLRS improves accuracy while preserving the model's discriminative capacity. Average best validation macro-F1 value was 0.9922 for logistic map-based CLRS and 0.9914 for cosine annealing. Average final validation macro-F1 value was 0.9891 for logistic map-based CLRS and 0.9884 for cosine annealing. Results reveal CLRS can be considered a complementary low-cost strategy in AI-based image classification. CLRS has been an applicable training strategy for lightweight architecture modes in ViT-based classification models to construct novel learning mechanisms and optimized models while attaining high levels of precision, timeliness and control.

Keywords: Computer vision systems, fractional gastrointestinal endoscopy images, vision transformer; MobileViTv2, AI-based fractional gastrointestinal endoscopy, diagnostic modalities, fractional-order calculus, nonlinear dynamics complexity.

References

[1] Karaca, Y., & Moonis, M. (2025). Mathematical neuron-neural-networks dynamics modeling and brain complexity of multicriteria fractal-based ensemble predictive algorithmic systems. Journal of Computational and Applied Mathematics, 117319.
[2] Kim, B. S., Lee, H. J., Park, J., Jeong, S. Y., Kim, M. J., Ahn, J. S., ... & Kim, S. (2025). Automated endoscopic image quality assessment for robust colorectal lesion detection. BMC Medical Imaging, 25(1), 473.

✉ Corresponding Author Email: *yeliz.karaca@ieee.org*

Integrated Optimization of Distributed Human–Robot Collaborative Disassembly Line Balancing, End-of-Life Product Transportation, and Outbound Distribution Routing

Kartal Aydinli✉, Zeynel Abidin Çil, Hande Öztop

İzmir Demokrasi University, Industrial Engineering Department, İzmir, Türkiye

Abstract

The growing awareness of sustainable principles has increased the importance of efficient recovery of end-of-life (EOL) products. In such systems, EOL products are collected from different supplier locations, transported to be processed in disassembly facilities, and subsequently distributed as recovered parts to customers or remanufacturing facilities. Although these operations are closely interrelated, transportation, disassembly, and distribution decisions are generally planned separately, which may increase operational costs. This study proposes an integrated optimization framework that simultaneously addresses EOL product collection, distributed human–cobot collaborative disassembly line balancing (DLB) and recovered parts distribution routing. The proposed study considers multiple distributed disassembly facilities in which human workers and cobots collaboratively perform disassembly operations at the same workstation. In this study, Mixed-Integer Linear Programming (MILP) and Constraint Programming (CP) models are developed to solve the proposed problem. MILP is used to obtain optimal solutions for small-size instances and establish a benchmark for solution quality. CP is employed to efficiently handle the complex combinatorial structure and rich constraint set of the integrated problem. Experiments are conducted on a set of test instances representing different problem characteristics. The results demonstrate the effectiveness of the proposed integrated approach in coordinating transportation, DLB, and distribution decisions within a unified framework. The performance of the proposed framework is also evaluated through an illustrative example and compared with the results obtained by solving these operational problems independently. Consequently, the proposed framework contributes to the design and operation of sustainable reverse logistics networks and distributed human–cobot collaborative disassembly line balancing by reducing operational costs.

Keywords: Human–Cobot Collaboration; Disassembly Line Balancing; Reverse Logistics, Mathematical Models

✉ Corresponding Author Email: *kartalaydinli2003@gmail.com*

Discrete-time prey-predator interaction with moonlight-driven predation and water-dependent growth

Ashraf Adnan Thirthar[1]✉ , Muhammad Aqib Abbasi[2], Asaad A.H AlZubaidi[3], Aiman Mukheimer[4], Thabet Abdeljawad[5]

[1] *Department of Mathematics, College of Eduction, University of Fallujah, Anbar, Iraq*
[2] *Department of Mathematics, Quaid-i-Azam University, Islamabad, Pakistan*
[3] *Medical Instruments techniques Engineering Department, Technical College of Engineering, Al-bayan University, Baghdad, Iraq*
[4] *Department of Mathematics and Sciences, Prince Sultan University, P.O. Box 66833, 11586 Riyadh, Saudi Arabia*
[5] *Department of Fundamental Sciences, Faculty of Engineering and Architecture, Istanbul Gelisim University, Avcılar- Istanbul, 34310, Türkiye*

Abstract

In this research work, a mathematical model for a discrete-time ecology of three species is considered that incorporates the interactions of prey, intermediate predator, and top predator, along with the environmental coupling effect. Existence criteria and locally asymptotically stable conditions of some equilibria for this ecosystem have been established through the use of the Jacobian matrix method and Jury stability criteria. In addition to that, analytical criteria for flip bifurcation and Neimark–Sacker bifurcation for such a discrete ecosystem have been provided, where changes in some critical ecological parameters cause the system to shift from its stable state of coexistence towards oscillations and even towards quasi-periodic behavior. In addition to that, sufficient conditions for the global attractivity of the interior equilibrium have been established. Moreover, the maximal Lyapunov exponent approach has been employed to determine the occurrence of chaos and regions of multistability and regime shifts. Finally, numerical simulations have been performed to validate theoretical findings.

Keywords: Stability analysis; Bifurcation analysis; Numerical simulation.

References

[1] Emam, H. H., El-Metwally, H., \& Hamada, M. Y. (2026). Dynamics of a discrete-time predator-prey model with exponential prey growth and saturated response. Scientific Reports, 16(1). https://doi.org/10.1038/s41598-026-41693-y.

[2] Sun, GQ., Zhang, HT., Wang, JS. et al. Mathematical modeling and mechanisms of pattern formation in ecological systems: a review . Nonlinear Dyn 104, 1677–1696 (2021). https://doi.org/10.1007/s11071-021-06314-5.

[3] Thierry, H., Sheeren, D., Marilleau, N., Corson, N., Amalric, M., \& Monteil, C. (2014). From the Lotka–Volterra model to a spatialised population-driven individual-based model. Ecological Modelling, 306, 287–293. https://doi.org/10.1016/j.ecolmodel.2014.09.022.

[4] Chen, Y., Duan, J., Li, D. et al. Stability and bifurcation in an ecological system under time-dependent environmental influences. Nonlinear Dyn 113, 28601–28616 (2025). https://doi.org/10.1007/s11071-025-11587-1.

✉ Corresponding Author Email: *a.a.thirthar@uofallujah.edu.iq*

An Adaptive PINN Approach for the Simulation of Magnetofluid Electroosmotic Flow of Micropolar Fluids through a Rotating Circular Microchannel in the Presence of AC Current and High Zeta Potential

Upasnaben D Vala✉, Ramakanta Meher

Sardar Vallabhbhai National Institute of Technology, Department of Mathematics, Surat, India

Abstract

Micropolar fluid [1], a special kind of non-Newtonian fluid, has many applications in biomedical, industrial, and engineering areas. This study presents a novel adaptive Physics-Informed Neural Network (PINN) framework [2] for investigating magnetofluid electroosmotic micropolar fluid flow through a porous circular rotating microchannel under the combined influence of a peripheral electric layer (PEL), alternating current (AC) magnetic field, pressure gradient, hydrophobic wall slip, and high wall zeta potential. The mathematical model consists of a coupled system of nonlinear, time-dependent partial differential equations governing the conservation of mass, linear momentum, angular momentum, and electric potential. The high zeta potential is incorporated without invoking the Debye–Hückel linearization, enabling an accurate description of the electric double layer, while the porous medium resistance is modeled through an appropriate permeability formulation. The effects of wall hydrophobicity are represented using a velocity slip Navior boundary condition [3], and the oscillatory electrokinetic forcing induced by the AC electric field is incorporated to analyze transient transport characteristics.

Keywords: Rotating circular microchannel, hydrophobic walls, high zeta potential, alternating current, porous medium, adaptive PINN framework

References

[1] Eringen, A. C. (1966). Theory of micropolar fluids. Journal of Mathematics and Mechanics, 16(1), 1–18.

[2] Barannia, H., & Esmaeilpour, M. (2022). On the application of physics informed neural networks (PINN) to solve boundary layer thermal-fluid problems. International Communications in Heat and Mass Transfer, 132, 105890. https://doi.org/10.1016/j.icheatmasstransfer.2022.105890

[3] Yu, X., Chen, X., Cui, J., Mu, J., Qiao, Y., & Zhang, Z. (2025). Magnetofluid EOF of a class of non-compressible micropolar fluids in a parallel plate microchannel with a hydrophobic wall at high wall zeta potential. Chinese Journal of Physics, 94, 79–96.

✉ Corresponding Author Email: *upasnavala010@gmail.com*

Comparative Evaluation of Deep Learning Architectures for State-of-Charge Estimation of Lithium-Ion Batteries

İrem Köksaldı✉, Sabri Can Karayel, Hakan Akça

Ege University, Electrical and Electronics Engineering Department, İzmir, Türkiye

Abstract

Accurate State of Charge (SOC) estimation is a fundamental task of electric vehicle battery management systems. It is critical for determining driving range, ensuring safe operation, and managing battery life. However, the nonlinear electrochemical behavior of lithium-ion batteries and their dependence on temperature and load conditions make SOC estimation a challenging problem. While traditional model-based methods require a detailed battery model and parameters, data-driven deep learning approaches have recently emerged as a strong alternative, estimating SOC directly from measurable battery data.

This study presents a comparative evaluation of five deep learning architectures for SOC estimation: a Convolutional Neural Network (CNN), Long Short-Term Memory (LSTM), Gated Recurrent Unit (GRU), and two hybrid models combining convolutional and recurrent layers (CNN-LSTM and CNN-GRU). All models were trained and tested on the open-access LG 18650HG2 lithium-ion battery dataset [1]. The input features are voltage, current, temperature, and their moving-average voltage and current, with SOC (%) as the target. All input and output variables are min-max normalized to [0, 1]. Since the dataset contains drive-cycle data collected at four ambient temperatures (−10, 0, 10, and 25 °C), the models are trained at certain temperatures and tested on data from a temperature not used during training. The main contribution is a comparison of how single and hybrid architectures generalize to previously unseen thermal operating conditions. Performance is assessed using complementary error metrics such as root mean square error (RMSE), mean absolute error (MAE), and the coefficient of determination (R^2). The comparative results and an analysis of each architecture's relative advantages will be presented at the conference.

Keywords: State of charge, lithium-ion battery, deep learning, recurrent neural networks, electric vehicles

Acknowledgements

This work was funded by The Scientific and Technological Research Council of Türkiye (TUBITAK) under research grant 125E871.

References

[1] Kollmeyer, P., Vidal, C., Naguib, M., & Skells, M. (2020). LG 18650HG2 Li-ion battery data and example deep neural network xEV SOC estimator script (Version 3) [Data set]. Mendeley Data. https://doi.org/10.17632/cp3473x7xv.3

✉ Corresponding Author Email: *iremkoksaldi18@gmail.com*

Spatial Heterogeneity in Provincial Housing Sales in Turkey: A Comparative Analysis of OLS, SAR, SEM, and GWR Models

İbrahim ARIK[1], İlhan Usta[2], Yeliz Mert Kantar[2]✉

[1] *Kütahya Dumlupınar University, Business Department, Kütahya, Turkiye*
[2] *Eskisehir Technical University, Department of Statistics, Eskişehir, Turkiye*

Abstract

This study investigates the spatial determinants of housing sales across 81 provinces of Turkey using 2024 cross-sectional data. The dependent variable is defined as the log-transformed number of housing sales per 1,000 inhabitants to remove scale effects inherent in raw sales counts. Four models are estimated and compared: Ordinary Least Squares (OLS), Spatial Autoregressive Model (SAR), Spatial Error Model (SEM), and Geographically Weighted Regression (GWR), a technique whose established applicability extends beyond socioeconomic analysis to environmental and meteorological phenomena exhibiting spatial variation, such as temperature and wind speed. Independent variables, net migration rate, urbanization rate, log-transformed building occupancy permits per capita, and youth population ratio are selected following Variance Inflation Factor (VIF) analysis to ensure the absence of multicollinearity (maximum VIF = 2.76). Global Moran's I confirms significant positive spatial autocorrelation in per-capita housing sales ($I = 0.372$, $p < 0.001$), and OLS residuals retain significant spatial dependence ($I = 0.123$, $p = 0.029$), motivating the use of spatial regression models. Among global spatial models, SEM outperforms OLS and SAR with the lowest AICc (7.13) and a significant spatial error parameter ($\lambda = 0.306$, $p = 0.032$). GWR achieves the best overall fit (AICc = 3.32; Adj. $R^2 = 0.644$) and reveals that the effect of net migration rate on per-capita housing sales varies significantly across provincial space, while urbanization rate, building permits, and youth population ratio exhibit spatially stable coefficients. These findings demonstrate that spatial regression models and GWR in particular provide superior characterization of Turkey's provincial housing market compared to conventional OLS.

Keywords: geographically weighted regression; spatial econometrics; housing sales; Turkey; spatial heterogeneity; per-capita normalization; multicollinearity

References

[1] Anselin, L. (1988). Spatial econometrics: Methods and models. Kluwer Academic Publishers.
[2] Anselin, L. (1995). Local indicators of spatial association — LISA. Geographical Analysis, 27(2), 93–115.
[3] Anselin, L., Bera, A. K., Florax, R., & Yoon, M. J. (1996). Simple diagnostic tests for spatial dependence. Regional Science and Urban Economics, 26(1), 77–104.
[4] Bitter, C., Mulligan, G. F., & Dall'erba, S. (2007). Incorporating spatial variation in housing attribute prices: A comparison of geographically weighted regression and the spatial expansion method. Journal of Geographical Systems, 9(1), 7–27.
[5] Brunsdon, C., Fotheringham, A. S., & Charlton, M. E. (1996). Geographically weighted regression: A method for exploring spatial nonstationarity. Geographical Analysis, 28(4), 281–298.
[6] Can, A. (1992). Specification and estimation of hedonic housing price models. Regional Science and Urban Economics, 22(3), 453–474.
[7] Demirel, U., & Caglar, M. (2023). Spatial econometric analysis of housing sales in Turkey: Evidence from NUTS-2 regions. Journal of Housing and the Built Environment, 38(2), 901–924.
[8] DiPasquale, D., & Wheaton, W. C. (1994). Housing market dynamics and the future of housing prices. Journal of Urban Economics, 35(1), 1–27.

✉ Corresponding Author Email: *ymert@eskisehir.edu.tr*

E-Bayes Estimation of the Rayleigh Distribution for Wind Energy

İlhan Usta[1]✉, Hanefi Gezer[1], İbrahim Arik[2], Yeliz Mert Kantar[1]

[1] *Eskisehir Technical University, Department of Statistics, Eskişehir, Turkiye*
[2] *Kütahya Dumlupınar University, Business Department, Kütahya, Turkiye*

Abstract

The Rayleigh distribution is one of the most widely used probability distributions for wind energy assessment due to its simplicity and effectiveness in modeling wind speed data. However, the accuracy of the estimated parameter has a significant impact on the reliability of wind energy estimation. In this paper, an E-Bayes estimation method is proposed for estimating the parameter of the Rayleigh distribution in wind energy applications. The proposed method yields a closed-form analytical estimator without requiring iterative optimization procedures or extensive numerical computations. Its performance is evaluated using real wind speed data and compared with those of the maximum likelihood, graphical, and moment estimation methods. The results demonstrate that the proposed E-Bayes method provides an effective and competitive alternative for parameter estimation in Rayleigh-based wind energy assessment.

Keywords: Rayleigh distribution, wind speed, wind energy, e-bayes estimation method

✉ Corresponding Author Email: *iusta@eskisehir.edu.tr*

On the fractional-order differential models for AI-Based optimization in sustainable computing systems under complex constraints

Dipesh[1], Jagjit Singh Dhatterwal[2], Longjun Zhan[3]✉, Haci Mehmet Baskonus[4,5]

[1] *SR University, Derpartment of Mathematics, Warangal, Telangana, India.*
[2] *SR University, School of Computer Science and Artificial Intelligence, Warangal, Telangana, India*
[3] *Shanghai Lixin University of Accounting and Finance, School of Mathematics and Statistics, Shanghai, China*
[4] *Faculty of Education, Department of Mathematics and Science Education, Harran University, Şanlıurfa, Türkiye*
[5] *Azerbaijan University of Architecture and Construction, Scientific Research Department, Baku, AZ1073, Azerbaijan*

Abstract

In this paper, a novel Fractional-Order Differential Equation (FODE) framework for optimization of the Sustainable Cloud and Edge computing framework is presented. We design a fractional-order, AI-based reinforcement learning method that models the state as a mixture of memory and evolves it by intelligently scheduling workloads across data centers distributed across different geographical zones, using real Google+Alibaba trace data. It incorporates neural policy networks, constraint regularization, and Pareto-optimal multi-objective optimization (MOO) with Caputo fractional derivatives to minimize both thermal violations and carbon emissions while satisfying deadlines. The system extends integer-order memory convolution algorithms by introducing augmented Lagrangian constraints to enable adaptive, long-term-aware decision-making, achieving superior performance compared with classical integer-order memory convolution approaches. FODE achieves substantial improvements in computational sustainability, computational stability, and efficiency under complex operational constraints through policy-gradient updates with violation penalties and dynamic load shifting towards renewable energy sources.

Keywords: Fractional-Order Systems, Pareto efficiency, Lyapunov stability, Green Artificial Intelligence, Resource Elasticity

References

[1] Arrassi, I., Arkhouch, S., El Myasse, I., Dib, F., Ben Meziane, K., & Benaya, N. (2026). A comprehensive review of ai-based wind power forecasting over multiple time horizons. Process Integration and Optimization for Sustainability, 1-23.
[2] Choi, S., Lee, K. H., Lee, H. J., Park, J. H., Kang, P. G., & Kam, J. (2026). Explainable AI-based optimization of facility operations for excessive NOx emission control: A case study of a solid refuse fuel combustion facility. Environmental Technology & Innovation, 104875.
[3] Dong, X., Wan, G., & Zeng, P. (2025). A heuristic-assisted deep reinforcement learning algorithm for flexible job shop scheduling with transport constraints. Complex & Intelligent Systems, 11(5), 210.
[4] Džamić, D., & Marković, A. (2026). SI/SIS/SIR models for malware propagation in P2P networks: Numerical analysis and perspectives for fractional-order extensions. Advances in Differential Equations and Control Processes.

✉ Corresponding Author Email: zhan_longjun@foxmail.com

Rich, Green and Safety Focused Route Optimization

Sena Şaylıg✉, Ibrahim Kucukkoc

Balikesir University, Industrial Engineering Department, Balikesir, Turkiye

Abstract

The Vehicle Routing Problem (VRP) is a cornerstone of logistics management [1]. Since traditional VRP models fall short in reflecting real-world complexities, the "Rich Vehicle Routing Problem" has emerged to incorporate multiple constraints simultaneously [2, 3]. This study develops a heterogeneous "Rich, Green, and Security-Focused Vehicle Routing Problem" model to optimize cash transfer operations in the banking sector [4, 5]. The proposed approach expands the existing literature by simultaneously minimizing operational costs, environmental impacts (carbon emissions), and security risks within the objective function. A mixed-integer linear programming model was developed, coded in Python, and solved using the Gurobi Optimization solver, which yields optimal solutions within reasonable computational times. For large-scale datasets exceeding the exact optimization time limit, the multi-objective NSGA-II Genetic Algorithm is utilized to obtain near-optimal results. To translate this mathematical framework into a functional tool for decision-makers, a Streamlit-based Multi-Objective Route Planning System web application was developed for dynamic scenario analysis. The model's performance was evaluated across distinct scenarios: standard, cost-focused, emissions-focused, safety-focused, rapid service, electric vehicle, traffic, carbon tax, and fleet-capacity scenarios. Optimization results are analyzed via interactive maps and graphs created with the Google Maps API and Python libraries integrated directly into the web application. By addressing environmental sustainability, this study provides significant contributions to both academic literature and practical sector applications.

Keywords: Cash transfer, green logistics, rich vehicle routing, optimization, modeling

Acknowledgements

This work was supported by the Scientific and Technological Research Council of Türkiye (TÜBİTAK) under the '2209-A Research Project Support Programme for Undergraduate Students' conducted by the Science Fellowships and Grant Programmes Directorate (BIDEB) with the project number 1919B012520102. We extend our sincere gratitude to TÜBİTAK for their invaluable support.

References

[1] Dantzig, G. B., & Ramser, J. H. (1959). The truck dispatching problem. *Management Science*, 6(1), 80–91.
[2] Toth, P., & Vigo, D. (Eds.). (2014). *Vehicle routing: problems, methods, and applications* (2nd ed.). SIAM.
[3] Lahyani, R., Khemakhem, M., & Semet, F. (2015). Rich vehicle routing problems: From a taxonomy to a definition. *European Journal of Operational Research*, 241(1), 1–14.
[4] Xu, G., Li, Y., Szeto, W. Y., & Li, J. (2019). A cash transportation vehicle routing problem with combinations of different cash denominations. *International Transactions in Operational Research*, 26(6), 2179–2198.
[5] Asghari, M., & Mirzapour Al-e-hashem, S. M. J. (2021). Green vehicle routing problem: A state-of-the-art review. *International Journal of Production Economics*, 231, 107899.

✉ Corresponding Author Email: senasaylig@gmail.com

Mathematical Analysis of a Cholera Model with Environmental Reservoir and Behavioral Awareness

Halime Gökkaya✉, Fırat Evirgen

Balıkesir University, Mathematics Department, Balıkesir, Türkiye

Abstract

Cholera remains a major public health challenge, particularly in regions with limited access to safe drinking water and adequate sanitation facilities. The transmission of the disease is influenced not only by interactions between susceptible and infected individuals but also by the persistence of Vibrio cholerae in contaminated water sources. In addition to these biological mechanisms, public awareness, hygiene practices, and sanitation behaviors play a crucial role in mitigating disease transmission during outbreaks. Motivated by these observations, this study proposes a novel mathematical model of cholera transmission that incorporates the interactions among human populations, environmental bacterial dynamics, and public awareness. The proposed model is analyzed to investigate its mathematical and epidemiological properties, and numerical simulations based on the fourth-order Runge–Kutta (RK4) method are carried out to illustrate the transmission dynamics of cholera under different epidemiological scenarios. The simulation results demonstrate the significant influence of public awareness and sanitation on reducing disease transmission and environmental bacterial concentration. The proposed model provides a useful framework for understanding cholera dynamics and may contribute to the development of effective public health intervention strategies.

Keywords: Cholera, mathematical modeling, behavioral dynamics, basic reproduction number, stability analysis, waterborne diseases, environmental reservoir.

Acknowledgements

This study was supported by TÜBİTAK through the 2210-A National Master's Scholarship Program.

References

[1] C. T. Codeço, "Endemic and epidemic dynamics of cholera: The role of the aquatic reservoir," BMC Infect. Dis., vol. 1, no. 1, art. 1, Dec. 2001, doi: 10.1186/1471-2334-1-1.

[2] E. J. Nelson, J. B. Harris, J. G. Morris Jr., S. B. Calderwood, and A. Camilli, "Cholera transmission: The host, pathogen and bacteriophage dynamic," Nat. Rev. Microbiol., vol. 7, no. 10, pp. 693–702, Oct. 2009, doi: 10.1038/nrmicro2204.

[3] Z. Mukandavire, S. Liao, J. Wang, H. Gaff, D. L. Smith, and J. G. Morris Jr., "Estimating the reproductive numbers for the 2008–2009 cholera outbreaks in Zimbabwe," Proc. Natl. Acad. Sci. U.S.A., vol. 108, no. 21, pp. 8767–8772, May 2011, doi: 10.1073/pnas.1019712108.

[4] P. van den Driessche and J. Watmough, "Reproductive numbers and sub-threshold endemic equilibria for compartmental models of disease transmission," Math. Biosci., vol. 180, no. 1-2, pp. 29–48, Nov. 2002, doi: 10.1016/S0025-5564(02)00108-6.].

[5] K. W. Brhane, A. G. Ahmad, H. Hina, and H. Emadifar, "Mathematical modeling of cholera dynamics with intrinsic growth considering constant interventions," Sci. Rep., vol. 14, no. 1, art. 4616, Feb. 2024, doi: 10.1038/s41598-024-55240-0.

✉ Corresponding Author Email: *halimegkky23@gmail.com*

The Effect of the Splitting Protocol on Performance in Dermatoscopic Skin Lesion Classification: A Controlled Measurement of Data Leakage

Lada Asankulova✉, Ali Konuralp

Manisa Celal Bayar University, Department of Mathematics, Manisa, Turkey

Abstract

Skin cancer is one of the most common cancers in the world, and early diagnosis has a direct effect on treatment success. Classifying skin lesions automatically from dermatoscopy images is an active research topic for clinical decision support systems. In this study, four deep learning architectures (DenseNet121, ConvNeXt-Tiny, ResNet50, and EfficientNet-B3) were tested on the HAM10000 dataset [1] for seven-class skin lesion classification. The models were compared in two scenarios. In the first scenario, the data was split at the lesion level, so images of the same lesion could not appear in more than one set. In the second scenario, data augmentation was applied before the split. This was done on purpose to create data leakage, and the same four models were retrained under this protocol. In both scenarios, class imbalance was handled with undersampling and WeightedRandomSampler. Albumentations was used for data augmentation [2], and OneCycleLR was used as the learning rate scheduler during training [3]. Each experiment was repeated with three random seeds (13, 21, 42), giving 24 trained models in total. The results are reported as mean and standard deviation. In the first scenario, DenseNet121 reached the highest test accuracy (77.39% ± 1.00), but the gaps between the models stayed within the standard deviations. In the second scenario, the test accuracy of every model went up. The mean test accuracy rose from 76.47% to 83.70%, an increase of 7.23 points. For DenseNet121, it rose from 77.39% to 86.95%. The size of the increase was different for each architecture (from 2.77 to 9.57 points), but it was positive in all twelve runs. This finding shows why a lesion-level split is necessary in medical imaging studies.

Keywords: Deep learning, convolutional neural networks, skin cancer classification, HAM10000, data leakage, lesion-level split, class imbalance.

References

[1] P. Tschandl, C. Rosendahl, and H. Kittler, "The HAM10000 dataset, a large collection of multi-source dermatoscopic images of common pigmented skin lesions," Scientific Data, vol. 5, no. 1, pp. 180161–180161, Aug. 2018, doi: 10.1038/sdata.2018.161.

[2] A. Buslaev, V. I. Iglovikov, E. Khvedchenya, A. Parinov, M. Druzhinin, and A. A. Kalinin, "Albumentations: Fast and Flexible Image Augmentations," Information, vol. 11, no. 2, p. 125, Feb. 2020, doi: 10.3390/info11020125.

[3] L. N. Smith and N. Topin, "Super-Convergence: Very Fast Training of Neural Networks Using Large Learning Rates," 2017, arXiv. doi: 10.48550/ARXIV.1708.07120.

✉ Corresponding Author Email: *asankulova60@gmail.com*

A QoS-Integration-Centric Taxonomy and Mathematical Modeling Perspective of Opportunistic Routing in Wireless Mesh Networks

Noumedia Ouarab ✉, Samra Boulfekhar, Djamil Aissani

University of Bejaia, Faculty of Exact Sciences, LaMOS Research Unit (Modeling and Optimization of Systems), Bejaia 06000, Algeria

Abstract

Opportunistic routing improves wireless mesh network performance by exploiting the broadcast nature of wireless links and allowing multiple candidate forwarders to participate in packet delivery. However, integrating Quality of Service into opportunistic routing remains challenging because protocols must balance reliability, delay, throughput, energy consumption, congestion, mobility, security, and duplicate suppression.

This paper presents a comparative analysis of QoS-aware opportunistic routing approaches in wireless mesh networks from a mathematical modeling and decision-process perspective. Based on the reviewed protocols, we propose a QoS-integration-centric taxonomy that groups existing approaches according to the stage where QoS is introduced in the routing process. The proposed taxonomy includes link-level, state-aware, coding-aware, flow-level, security/trust-aware, mobility-aware, and analytical modeling approaches.

The analysis highlights the lack of unified multi-objective QoS solutions and identifies open issues related to candidate coordination, mathematical modeling, and adaptive optimization for future protocol design.

Keywords: Wireless Mesh Networks, Opportunistic Routing, Quality of Service, Taxonomy, Mathematical Modeling, Multi-objective Optimization.

References

[1] O. S. Eyobu and K. Edwinah, "A Deep Learning-Based Routing Ap-proach for Wireless Mesh Backbone Networks," IEEE Access, vol. 11, pp. 49509–49518, 2023.

[2] M. A. M. Khah, N. Moghim, N. Gholami, and S. Shetty, "Energy-Efficient Multi-Rate Opportunistic Routing in Wireless Mesh Networks," IEEE Access, vol. 11, pp. 97466–97477, 2023.

[3] Y. Zhao and G. Srivastava, "A Wireless Mesh Opportunistic Network Routing Algorithm Based on Trust Relationships," IEEE Access, vol. 10, pp. 4786–4793, 2022.

[4] J.-B. Bordier, C. Merlhe, P. Fabian, S. Baey, D. Garnaud, K. Bussereau, Livolant, and C. Gueguen, "Buffer Occupancy and Link State Opportunistic Routing for Wireless Mesh Networks," Wireless Networks, vol. 27, no. 6, pp. 4133–4150, 2021.

[5] M. Paulon J. V., B. J. O. de Souza, and M. Endler, "Opportunistic Routing towards Mobile Sink Nodes in Bluetooth Mesh Networks," in Proceedings of the 18th International Conference on Wireless Networks and Mobile Systems (WINSYS), pp. 67–75, 2021.

[6] K. Haseeb, I. U. Din, A. Almogren, N. Islam, and A. Altameem, "RTS: A Robust and Trusted Scheme for IoT-Based Mobile Wireless Mesh Networks," IEEE Access, vol. 8, pp. 68379–68390, 2020.

[7] A. Fang, L. Cui, Z. Zhang, Z. Sheng, M. Zhu, and X. Zhang, "An Op-portunistic Routing Strategy Based on Network Coding in Multi-Speed Processing Environment," in Proceedings of the 2019 International Conference on Artificial Intelligence and Advanced Manufacturing (AIAM), Dublin, Ireland, pp. 1–6, 2019.

✉ Corresponding Author Email: *noumedia.ouarab@univ-bejaia.dz*

Subdivisions of Sierpinski Triangle Graphs and Their Topological Graph Indices

Ismail Naci Cangul[1]✉, Aykut Sen[2], Aysun Yurttas Gunes[1], Ilker Kucukoglu[2],
Hacer Ozden Ayna[1], Fethi Abdullah Avsar[1]

[1] *Bursa Uludag University, Department of Mathematics, Bursa, Turkey*
[2] *Bursa Uludag University, Department of Industrial Engineering, Bursa, Turkey*

Abstract

In Fractals, Chaos Theory and Measure Theory, the geometrical figures called Sierpinski triangles, carpets, pentagons, hexagons, etc. have interesting applications. Together with the advances in application areas of graphs and network structures, this interest moved towards these new areas in the last few decades. Especially, choosing the correct network structure for some real-life problem has become vital in many applications. Therefore, geometrical figures are started to be used as network structures and models for daily problems. Here, one of the Sierpinski structures, Sierpinski triangle, is transformed to a graph and studied by graph theoretical tools. In particular, subdivision and r-subdivision graphs, as two of the derived graphs. By means of vertex and edge partitions of all these graph classes, some indices are calculated.

Keywords: Sierpinski triangle graph, subdivision graph, topological graph index

Acknowledgements

This study was supported by Bursa Uludag University Research Projects Coordination Office under the Grant Number FYL-2026-2659 and FGA-2025-2204. The authors thank to BUU BAP Unit for their support.

References

[1] Ranjini P S, Lokesha V, Cangul I N (2011). On the Zagreb Indices of the Line Graphs of the Subdivision Graphs, Applied Mathematics and Computation, 218 (3), 699-702

[2] Togan, M, Yurttas A, Cangul I N (2016). All versions of Zagreb indices and coindices of subdivision graphs of certain graph types, Advanced Studies in Contemporary Mathematics, 26 (1), 227-236

✉ Corresponding Author Email: *cangul@uludag.edu.tr*

Advanced qualitative and sensitivity analysis of deterministic Lanchester-type area-fire warfare models

Ioannis D. Sfikas✉

National Technical University of Athens, School of Applied Mathematics and Physical Sciences, Athens, Greece

Abstract

This paper presents a rigorous mathematical investigation into the qualitative behavior and parameter estimation framework of the deterministic Lanchester area-fire warfare model. Representing a non-isolated, nonlinear dynamical system, the area-fire model possesses a unique geometric structure where the equilibrium states form a continuous one-dimensional manifold along the coordinate axes rather than isolated points. Due to this inherent non-hyperbolicity and the presence of a zero eigenvalue, classical linearization techniques and the Hartman-Grobman theorem are insufficient to fully characterize the system's asymptotic behavior. To resolve this, we employ invariant manifold theory alongside LaSalle's Invariance Principle, constructing a strict linear Lyapunov function based on the weighted combat capabilities of the opposing forces. This approach rigorously proves the global asymptotic convergence of all admissible trajectories toward the equilibrium manifold, ensuring that military resource dissipation is irreversible and that self-sustained oscillations or limit cycles are structurally impossible.

Furthermore, we address the challenge of data-driven parameter identification, which is critical for operational planning and historical battle reconstructions. We formulate a nonlinear inverse problem utilizing a least-squares optimization functional to estimate the combat effectiveness coefficients from discrete battlefield observations. To evaluate the robustness of these estimators, a six-dimensional augmented forward sensitivity system is derived by differentiating the governing state equations using the product and chain rules. Local parameter perturbations reveal a mathematical singularity in relative sensitivity when the forces reach a tactical stalemate, matching real-world military operational experiences where minor non-numerical factors can entirely invert the engagement outcome. Finally, codimension-one bifurcation analysis demonstrates that the spectral properties and topological structure of the phase portrait remain invariant under positive parameter perturbations, establishing the robust structural stability of the model.

Keywords: Lanchester equations, Nonlinear dynamical systems, Invariant manifolds, Lyapunov stability, Forward sensitivity equations, Bifurcation theory.

References

[1] Adams, Eldridge S. and Mesterton-Gibbons, Michael, Lanchester's attrition models and fights among social animals, Behavioral Ecology, 14(5), (2003), 712-723.

[2] Ancker Jr., Clinton J., A proposed foundation for a theory of combat, Naval Research Logistics (NRL), 42(3), (1995), 311-343.

✉ Corresponding Author Email: *sfikas@hotmail.com*

A Computationally Stable Memory-Aware Physics-Informed Neural Network Framework with Caputo Fractional Operators: Convergence Theory and Applications to Long-Memory Data

Aytekin Enver[1], Mehmet Yavuz[2,3] ✉

[1] *Gazi University, Department of Mathematics, Faculty of Science, Ankara, Türkiye*
[2] *Necmettin Erbakan University, Department of Mathematics and Computer Sciences, Faculty of Science, Konya, Türkiye*
[3] *Kyrgyz–Turkish Manas University, Department of Applied Mathematics and Informatics, Bishkek 720038, Kyrgyzstan*

Abstract

Physics-informed neural networks provide an effective framework for integrating governing equations with data-driven learning, but their application to systems with long-range memory remains computationally challenging. This study introduces C-fPINN, a computationally stable and memory-aware physics-informed neural network based on the Caputo fractional derivative. The framework combines the Alikhanov L2-1sigma discretization with sum-of-exponentials fast convolution, preserving the power-law memory structure of the Caputo operator while substantially reducing computational storage requirements. A unified learning objective is developed by incorporating data fidelity, fractional residual, initial and boundary conditions, and memory-aware regularization. Theoretical analysis establishes universal approximation capability, convergence of the discretized residual, and a generalization bound for the neural network component. The fractional order is learned jointly with the network parameters, enabling direct identification of memory effects from data. The proposed framework is validated using a controlled fractional benchmark, high-frequency S&P 500 volatility data, and a fractional reaction-diffusion SEIR epidemic model calibrated to COVID-19 incidence data. Numerical comparisons and ablation studies demonstrate improved predictive accuracy, computational efficiency, and robustness over classical and competing fractional learning approaches.

Keywords: Physics-informed neural networks, long-memory time series, convergence analysis

References

[1] Farea, A., Yli-Harja, O., & Emmert-Streib, F. (2024). Understanding physics-informed neural networks: Techniques, applications, trends, and challenges. AI, 5(3), 1534–1557.
[2] Khan, M.R., & Ali, S. (2025). Fractional-order gradient approach for optimizing neural networks: A theoretical and empirical analysis. Chaos, Solitons & Fractals, 190, 115022.
[3] Faroughi, S.A., Pawar, N., Fernandes, C., Raissi, M., Das, S., Kalantari, N.K., & Mahjour, S.K. (2025). Physics-informed neural networks in materials modeling and design: A review. *Archives of Computational Methods in Engineering*, 32.

✉ Corresponding Author Email: *mehmetyavuz@erbakan.edu.tr*

Physics-Informed Neural Network-Based Modeling of Cancer Dynamics under Combined Impact of Chemotherapy and Immunotherapy

Hardik Joshi[1], Mehmet Yavuz[2,3]✉

[1]*Department of Mathematics, LJ Institute of Engineering and Technology, LJ University, Ahmedabad-382210, India*
[2]*Department of Mathematics and Computer Sciences, Necmettin Erbakan University, 42090, Konya, Türkiye*
[3]*Department of Applied Mathematics and Informatics, Kyrgyz-Turkish Manas University, Bishkek 720038, Kyrgyzstan*

Abstract

Cancer is a highly heterogeneous and dynamic disease driven by complex interactions between malignant cells, immune cells, and the surrounding tumor microenvironment. Tumor progression and therapeutic response are governed by a delicate interplay between tumor growth, immune-mediated recognition and elimination, and treatment-induced changes in the cellular environment. Among the major components of the antitumor immune response, cytotoxic immune cells play a crucial role in identifying and eliminating malignant cells, while tumor cells can develop mechanisms to evade immune surveillance. Chemotherapy can further alter these interactions by directly suppressing tumor cells and modulating the activity and abundance of immune populations. A mathematical model is developing to investigate the dynamics of tumor–immune interactions under the combined action of chemotherapy and immunotherapy. The model incorporates biologically relevant tumor and immune components and describes how their interactions influence tumor progression, immune-mediated tumor control, and therapeutic outcomes. We employ a Physics-Informed Neural Network (PINN), a machine-learning-based approach that incorporates the governing differential equations and initial conditions directly into the learning process. The PINN framework provides an efficient data-independent approach for approximating the solutions of the proposed nonlinear dynamical system and offers a flexible alternative to conventional numerical solvers. The PINN-generated solutions are validated against solutions obtained using a standard numerical technique, demonstrating good agreement and confirming the reliability of the proposed machine-learning approach. Furthermore, numerical and PINN-based simulations are performed to investigate the influence of key model parameters and to provide insights into the effectiveness of combined chemotherapy and immunotherapy. The findings demonstrate the potential of integrating mathematical modeling with physics-informed machine learning for analyzing complex cancer dynamics.

Keywords: Physics-Informed Neural Network, cancer dynamics, chemotherapy, immunotherapy

References

[1] De Pillis, L. G., Gu, W., & Radunskaya, A. E. (2006). Mixed immunotherapy and chemotherapy of tumors: modeling, applications and biological interpretations. Journal of theoretical biology, 238(4), 841-862.
[2] M. Raissi, P. Perdikaris and G. E. Karniadakis. (2019). Physics-informed neural networks: A deep learning framework for solving forward and inverse problems involving nonlinear partial differential equations, Journal of Computational physics, 378, 686-707.

✉Corresponding Author Email: *mehmetyavuz@erbakan.edu.tr*

Initial-Value Admissibility and Left-Half-Plane Stability of Power-Law Fractal-Fractional Systems

Zakia Hammouch[1]✉, Zaid Odibat[2]

[1] *Department of Sciences, École Normale Supérieure, Moulay Ismail University, Meknès, Morocco*
[2] *Department of Mathematics, Faculty of Science, Al-Balqa Applied University, Salt 19117, Jordan*

Abstract

Fractal-fractional operators have been increasingly used to describe dynamical systems in which nonlocal memory and nonclassical temporal scaling occur simultaneously [1,2]. Despite this growing use, the analytical consistency of the associated initial-value problems requires particular care because different integral conventions may lead to inequivalent evolution equations. In this work, we examine the Caputo-type power-law fractal-fractional derivative and identify a structural admissibility issue that directly affects the interpretation of prescribed initial data. Starting from the defining weighted derivative, we reconstruct the corresponding integral formulation and obtain a positive Volterra operator whose short-time behaviour is governed by the effective exponent $\alpha+\beta-1$. This shows that, when $\alpha+\beta-1\leq 0$, a continuous solution cannot in general depart from a non-equilibrium initial state in the usual manner, so the initial condition must satisfy an additional compatibility requirement. We then derive a multiplicative representation of the associated scalar evolution problem. The resulting symbol belongs to the Bernstein-function framework [3], which permits the construction of an entire generalized relaxation function and clarifies the qualitative behaviour of the linear system. In particular, the relaxation function decays for spectral parameters in the negative real half-plane and grows in the positive real half-plane. The argument is extended to finite-dimensional linear systems, including defective matrices, through the corresponding matrix functional calculus. Finally, an illustrative model is used to compare two competing integral conventions. Although both formulations appear formally similar, they generate different short-time dynamics and therefore lead to distinct interpretations of the same prescribed initial state. These results separate initial-value admissibility from spectral stability and show why the integral representation must be verified before applying established fractional stability criteria such as the sector condition [4]. A complete characterization of the stability region for general complex spectral parameters remains open.

Keywords: fractal-fractional operator, admissible initial data, Bernstein symbol, generalized relaxation, matrix stability

References

[1] Atangana, A. (2017). Fractal-fractional differentiation and integration: Connecting fractal calculus and fractional calculus to predict complex system. Chaos, Solitons & Fractals, 102, 396-406.
[2] Atangana, A., & Akgül, A. (2021). On solutions of fractal fractional differential equations. Discrete and Continuous Dynamical Systems - S, 14, 3441-3457.
[3] Schilling, R. L., Song, R., & Vondraček, Z. (2012). Bernstein Functions: Theory and Applications (2nd ed.). De Gruyter, Berlin.
[4] Matignon, D. (1996). Stability results for fractional differential equations with applications to control processing. In Computational Engineering in Systems Applications, Vol. 2, IMACS-IEEE/SMC, 963-968.

✉ Corresponding Author Email: z.hammouch@umi.ac.ma

Mixed Sumudu–Adomian Method for Two-Dimensional Nonlinear Fuzzy Integral Equations

Artan F. Alidema[1]✉, Frederik Dara[2]

[1] *Department of Mathematics, Faculty of Mathematical and Natural Science, University of Prishtina, Kosovo*
[2] *Department of Applied Mathematics, Faculty of Natural Science, University of Tirana, Albania*

Abstract

A numerical method for solving two-dimensional nonlinear Volterra-Fredholm fuzzy integral equations (2D-NVFFIE) of the second kind is introduced. First, the nonlinear Volterra-Fredholm fuzzy integral equation is converted into a system of nonlinear Volterra-Fredholm integral equations in the crisp case using α-cuts. We then apply the Sumudu Transform combined with the Adomian Decomposition Method (Sumudu-ADM) to solve the system efficiently without requiring discretization, perturbation, or linearization. The existence, uniqueness of the fuzzy solution, and convergence of the proposed Sumudu-ADM scheme are established theoretically. Finally, a numerical example is presented to illustrate the accuracy and applicability of the proposed technique.

Keywords: Integral equations, Sumudu Transform, Sumud Adomian Decomposition method

References

[1] Al-Taee, L.H., & Al-Hayani, W. (2022). The combined Sumudu transform-Adomian decomposition method for solving systems of linear Fredholm-Volterra integro-differential/integral equations. *AIP Conference Proceedings*, 2398, 060075. https://doi.org/10.1063/5.0094517.

[2] Hassan, W.A. (2025). Solving nonlinear Volterra-Fredholm integro-differential equations of the second kind by combining the Sumudu transform and the Adomian decomposition method. *Derna Academy Journal for Applied Sciences*, 3(2), 161–172. https://doi.org/10.71147/d1hnt028.

[3] Amer, Y.A., Mahdy, A.M.S., & Namoos, H.A.R. (2018). Application of Sumudu decomposition method to solve nonlinear system Fredholm and Volterra integrodifferential equations. *International Journal of Applied Engineering Research*, 13(11), 9588–9595.

[4] Alidema, A.F. (2022). Applications of double fuzzy Sumudu Adomian decomposition method for two-dimensional fuzzy Volterra integral equations. *European Journal of Pure and Applied Mathematics*, 15(3), 1363–1375. https://doi.org/10.29020/nybg.ejpam.v15i3.4470.

[5] Al-saar, F.M., & Ghadle, K.P. (2021). Usage of numerical methods to solve nonlinear mixed Volterra-Fredholm integral equations and their system. *Results in Nonlinear Analysis*, 4(4), 244–262. https://doi.org/10.53006/rna.988774.

✉ Corresponding Author Email: *artan.alidema@uni-pr.edu*

Cryptocurrency Price Prediction Using an Automatic Programming Method

Fatma Selen Madenoğlu[1]✉, Mümin Emre Şenol[2], Lale Özbakır[3]

[1] *Abdullah Gül University, Business Administration Department, Kayseri, Türkiye*
[2] *Manisa Celal Bayar University, Industrial Engineering Department, Manisa, Türkiye*
[3] *Erciyes University, Industrial Engineering Department, Kayseri, Türkiye*

Abstract

Cryptocurrency markets, with their high price volatility and complex dynamics, make accurate price prediction difficult, increasing the need for reliable prediction models to support investment decisions. Studies systematically examining the contribution of different groups of technical indicators to prediction success in cryptocurrency price forecasting are limited in the literature. In this study, an automatic programming method was used to predict Bitcoin closing prices hourly. In this study, technical indicators were divided into different groups: trend, momentum, volatility, volume, and price-based indicators. Thus, a comparative evaluation was conducted to determine which technical indicator group contributed more to prediction performance. Mean Absolute Error (MAE), Mean Squared Error (MSE), Root Mean Square Error (RMSE), Mean Absolute Percentage Error (MAPE), and Coefficient of Determination (R^2) metrics were used to examine the model's performance. The results indicate that the technical indicator groups' prediction performance varied significantly. In addition to providing an explainable method based on automated programming to the literature on cryptocurrency price prediction, this study reveals the relative efficacy of several sets of technical indicators, which can help investors and researchers make informed decisions.

Keywords: Cryptocurrency; Price prediction; Automatic programming

✉ Corresponding Author Email: *selen.madenoglu@agu.edu.tr*

Author Index

Abdulkadir C. Yucel 51
Abdulkadir Taşdelen 57
Abdullah Usame Gündeşli 121
Abdulwasea Alkhazzan 17
Ahmet Akusta 126
Ahmet Çoban 116
Ahmet Sahiner 17
Aiman Mukheimer 147
Akif Akgül 145
Akmalbek Abdusalomov 64
Alejando Torres-Sánchez 143
Ali Ahmadian 14
Ali Bağcı 89
Ali Berkol 33
Ali Konuralp 57, 132, 155
Ali Rıza Alan 38, 48
Ali Yiğit Sabaner 105
Alptekin Durmuşoğlu 102
Amin Jajarmi 20
André Lopes 43
Anett Rácz 108, 114
Arda Yalcinkaya 51
Artan F. Alidema 162
Artem Naumovets 109
Asaad A.H AlZubaidi 147
Ashraf Adnan Thirthar 147
Aslan Deniz Karaoglan 18
Ayhan Özgür Toy 75, 83, 86
Aykut Sen 125, 157
Ayse Nur Altunkaya 60
Aysun Yurttas Gunes 125, 157
Aytekin Enver 159
Azmi Ali Altintas 38
Azra Nur Çelik 124
Baki Çiçek 144
Barış Namlı 38, 48
Berkay Emin 145
Berkin Yeginoğlu 83
Betul Yagmahan 80
Beyza Çermikli 137
Bilal Ervural 129
Bora Palandız 81
Burak Aşkın 122
Burcu Gurbuz 4, 18
Cagatay Iris 90
Çağrı Latifoğlu 44
Canan Bozkaya 82
Cansu Aksu 84
Charos Khidirova 64
Cihan Bayındır 38, 48
Cüneyt Ceyhan 128
Daniel Santos-Oliván 143
Demet Ersoy Özdek 50
Deniz İlaslan 135
Deniz Türsel Eliiyi 71
Derya Altıntan 61
Didem Eylenen 81
Dimiter Prodanov 69
Djamil Aissani 156
Djelloul Ziane 85
Dongping Song 90
Dumitru Baleanu 3, 4, 6, 10, 15, 19, 20, 85
Ebiwonjumi Ayooluwade 112
Ebru Açikgöz 91
Ece Nur Polat 105
Ekin Oktay 39
Elif Aydan Bike 80
Elif Güner 124
Elif İlkin Ersoy 50
Elif Tarakçı 94, 95, 137
Emine Es Yurek 127
Emre Akusta 126
Esma Canhasi Kasemi 106
Esma Ulutaş 36
Esra Çelik 76
Eszter Kiss 114
F. Sidre Oğlakkaya 74
Fatih Ozaydin 38
Fatma Neşe Özen 75
Fatma Nur Kaya Sağlam 49
Fatma Selen Madenoğlu 163
Fatma Tokmak Fen 115, 139, 140
Fehmi Burçin Özsoydan 67
Fırat Evirgen 4, 17, 31, 154
Frederik Dara 162
Furkan Keskin 120
Furkan Mert Gümüş 46
Gabriel Torregrosa-Cortés 143
Gerhard Wilhelm Weber 4, 6, 12, 18
Gökçe Özaltun Şimşek 100
Gökhan Karcıoğlu 93
Gözde Karapelit 132
Gözde Yazgı Tütüncü 100
Gülden Mülayim 63
Gülşen Yaman 84, 95, 136, 142
Hacer Ozden Ayna 125
Haci Mehmet Baskonus 110, 152
Hakan Akça 22, 149
Halil Sinoplugil 142
Halime Gökkaya 154
Halis Aygün 124
Halit Süleyman Türkmen 39
Haluk Eliş 104
Hamid Orhun Tur 56
Hande Öztop 146
Hanefi Gezer 151
Hardik Joshi 160
Haris Calgan 87
Harun Selvitopi 77
Hasan Hüseyin Yıldırım 126
Hassan Kamil Jassim 85
Hassan Mohammed 101
Helin Su Acar 86
Hidekazu Yoshioka 62, 65

Hivda Elçi 38
Hüseyin Avni Es 121, 122
Huseyin Merdan 21
Hüseyin Şeker 6, 11
İbrahim Arik 150, 151
Ibrahim Kucukkoc 4, 18, 41, 153
İdil Gökçe Demirtaş 33
İlhan Usta 150, 151
Ilker Kucukoglu 125, 127, 157
İlknur Tükenmez 45
Ioannis D. Sfikas 158
İrem Köksaldı 149
İsmail Caner 118
Ismail Naci Cangul 125, 157
Ismet Temaj 106
Jagjit Singh Dhatterwal 152
Javid Ali 134
Jordan Hristov 3, 4, 6, 13, 22
Juthika Mahanta 78
Kadriye Filiz Balbal 58
Kartal Aydinli 146
Keiko Arase 65
Kerem Ugurlu 107
Khaddouj Taifi 103
Kutay Pekşen 135
Lada Asankulova 155
Lajos Tóth 108
Lale Özbakır 163
Longjun Zhan 152
Mahmut Ali Gökçe 81
Maíra Aguiar 6, 11
Mario Raso 111
Mehmet Ali Kaygusuz 97, 99
Mehmet Çeçen 131
Mehmet Onur Fen 115, 139, 140
Mehmet Yavuz 4, 159, 160
Melih Ağraz 99
Melih Ali Pacaci 127
Melike Kaysal 68
Melike Sultan Karasu Asnaz 117, 123
Melissa Bilge Karadere 135
Meryem Abdullahaljouma 92
Metin Demirtas 20, 87
Miraç Huzeyfe Güner 129
Mohamed Fihri 72
Mohammed Alabdullah 37
Mountassir Hamdi Cherif 85
Muhammad Aqib Abbasi 147
Muhammed Berat Altınok 128
Muhammed Ishfaq Khan 49
Munarbek Aidaraliev 130
Mümin Emre Şenol 163
Münevver Tezer-Sezgin 52
Murat Erhan Balci 120, 128
Murat Güzeltepe 35
Musa Sina Ertuğrul 57
Nazlı Karataş Aygün 104
Necati Ozdemir 3, 4, 20, 70, 103, 111, 112, 116
Nejat Tukenmez 40
Neriman Kartal 98
Neriman Şolt 35
Nidanur Basocak 127
Nigorakhon Nasimova 64
Noumedia Ouarab 156
Okan Kon 118
Oktay Karakaya 120, 128
Oktay Yilmaz 41, 42
Oluwaseun Olumide Okundalaye 111, 112
Omar Jellouli 72
Ömer Nedim Kenger 92
Ömür Uğur 32
Önder Bulut 86
Oya Tarhan Bal 93
Özge Çelik 58
Pelin Şenel 52, 66
Pınar Yunusoğlu 67
Praveen Agarwal 6, 12
Ramakanta Meher 148
Ramazan Altay 136
Ramazan Yaman 3, 4, 17, 22, 84, 95, 105
Rashid Nasimov 64
Recep Duranay 137
Reha Yapali 57
Ritu Bhuyan 78
Rommel G. Regis 130, 133
Ruşen Kaya 115
Sabri Can Karayel 149
Sadettin Durmuş Talipoğlu 138
Safaa Kahil 72
Samet Kürşat Başol 102
Samra Boulfekhara 156
Sara Taheri 38, 48
Sebahattin İkikardeş 58
Seda Ermis 59
Selçuk Alp 88
Selçuk Han Aydin 53, 55
Semiha Erkovan 71, 79
Semra Doğruöz 91
Sena Şaylıg 153
Serkan Demiriz 46
Seta Bogosyan 40
Sevdanur Genç 141
Sevin Gümgüm 50, 100
Seyma Mercan 90
Seza Dinibutun 47
Shokoufeh Ghezeljeh 55
Soheil Salahshour 14
Songul Kaya Merdan 21
Srinivasan Natesan 32
Suat Onur 95
Sulaiman Mohammed Ibrahim 101
Suleiman M. Sharkh 87
Süleyman Cengizci 32
Süleyman Mete 92
Sultan Sütlü 96
Sumati Kumari Panda 23
Sümran Gücü 70
Syed Shakaib Irfan 54

Taha Yılmaz 31
Taylan Demir 85
Thabet Abdeljawad 23, 147
Tugba Aydemir 34
Türkay Dereli 102
Uğur Eliiyi 79
Ulviye Savaş 88
Upasnaben D Vala 148
Vahid Amin-Ghafari 37
Vildan Özkir 88
Vinícius Silva 43
Vladyslav Cherkashyn 109
Waleed Adel 17, 110
Xiaofan Jia 51
Yang Liu 51
Yaren Ozbek 127
Yassine Sabbar 17, 103
Yeliz Karaca 4, 15, 19, 145
Yeliz Mert Kantar 150, 151
Young-Im Cho 6, 10, 64
Yücel Öztürkoğlu 75
Yunus Eroğlu 102, 119
Yusuf Alaca 145
Yusuf Toprak 123
Zaid Odibat 161
Zakia Hammouch 161
Zehra Kamışlı Öztürk 135
Zeynel Abidin Çil 146
Zeynep Nur Köstepen 79
Zühra Güneş 89

Subject Index

Accessibility 79, 137
Adam Optimizer 63, 112
Adaptive Control 40, 96
Approximate Solutions 50, 132
Artificial Intelligence 33, 68, 71, 75, 77, 87, 111, 117, 126, 135, 145, 152
Asymptotic Unpredictability 139, 140
Basic Reproduction Number 70, 154
Bayesian Optimization 72, 130
Bifurcation Analysis 147, 158
BIST 44, 84
Caputo Fractional Derivative 110, 159
Carbon Emissions 81, 94, 116, 138, 152, 153
Carbon Footprint 95, 117, 144
Carbon Intensity 84, 126
Chaos 87, 98, 139, 147, 157
Class Imbalance 135, 155
Combinatorial Optimization 33, 41, 125
Conservation Laws 77, 109
Convergence Analysis 101, 112, 159
Convolutional Neural Networks 34, 155
Cooperative Game Theory 88, 119
Cryptocurrency 163
Data Leakage 125, 135, 155
Decision Support System 95, 105, 142
Deep Learning 33, 34, 40, 49, 57, 64, 77, 87, 103, 141, 145, 149, 155
Demand Forecasting 75, 118
Demand Uncertainty 81, 129
DenseNet 103, 155
Differential Equations 32, 36, 48, 50, 53, 62, 63, 70, 77, 85, 109, 110, 116, 132, 134, 140, 143, 148, 160
Digital Twin 37, 56
Disaster Management 48, 127
DRBEM 52, 74
Electric Vehicle Charging Stations 87, 131
Electric Vehicles 129, 131, 149
Energy Efficiency 84, 126, 142
Energy Intensity 84, 126
Equilibrium Analysis 31, 70, 102
Evolutionary Algorithms 33, 133
Explainable AI 111, 126
Facility Location 104, 129
Feature Engineering 58, 59, 72
Finite Element Analysis 39, 128
Fixed Point Theorem 134, 139
Fourier Analysis 38, 97
Fuzzy Logic 68, 102
Genetic Algorithm 39, 41, 80, 86, 153
Gradient Descent 111, 112, 145
Heat Transfer 60, 74, 118
Heuristics 42, 67, 86
High-Dimensional Black-Box Optimization 130, 133
Humanitarian Aid 45, 127
Hybrid Methods 32, 71
Image Denoising 101, 124
Integral Equations 139, 162
Inverse Problems 63, 93, 143
K-Means 113, 121
Life Cycle Assessment 94, 95
Local Stability 70, 96, 98, 116
Loss Function 47, 56, 57, 63, 77, 109, 112
LSTM 59, 72, 87, 122, 149
Lyapunov Stability 111, 116, 152, 158
Machine Learning 40, 59, 61, 65, 72, 75, 76, 77, 79, 107, 112, 117, 123, 125, 135, 138, 143, 160
Mathematical Modeling 31, 50, 63, 68, 70, 71, 76, 94, 96, 144, 146, 147, 148, 154, 156, 160
Memory Effects 98, 110, 134, 159
Metaheuristic Optimization 33, 119
MHD 53, 55
Mixed-Integer Linear Programming 81, 108, 127, 142, 146, 153
Mixed-Integer Programming 75, 127, 129
Monte Carlo Simulation 116, 137
Multi-Criteria Decision-Making 71, 84
Multi-Objective Optimization 94, 105, 152, 156
Natural Gas 116, 138
Neural Networks 32, 34, 40, 47, 61, 63, 77, 97, 109, 112, 115, 126, 141, 143, 149, 155, 159
Nonlinear Dynamical Systems 70, 158
Numerical Simulation 110, 147
Optimal Transport 97, 99
Parameter Estimation 100, 151, 158
Parametric Analysis 74, 82
Periodic Solutions 43, 96, 98
Photovoltaic 58, 123, 131
Physics-Informed Machine Learning 40, 160
Physics-Informed Neural Network 32, 40, 47, 56, 63, 77, 109, 141, 143, 148, 159, 160
PINN 47, 56, 63, 77, 109, 141, 143, 148, 160
Predictive Maintenance 56, 123
Queueing Theory 83, 137
Radial Basis Function 130, 133, 141
Random Forest 72, 76, 125
Reinforcement Learning 33, 37, 40, 111, 152
Renewable Energy Systems 87, 122
Resource Allocation 37, 79, 80, 92
Reverse Logistics 129, 146
Robust Optimization 81, 88
Route Optimization 42, 153

Scheduling 37, 56, 67, 79, 80, 81, 86, 88, 104, 105, 108, 122, 145
Sensitive Dependence on Initial Conditions 139, 140
Spatial Data 97, 99
Stability Analysis 116, 147, 154
Stochastic Differential Equations 62, 116, 134
Surrogate Model 56, 133
Sustainable Computing 78, 117, 152
Synchronous Generators 120, 128
Thermal Management 74, 136
Traveling Salesman Problem 42, 108
Well-Posedness 31, 62
Wind Energy 116, 117, 151
Wind Speed 117, 118, 123, 150, 151