Lecture Notes in Computer Science **16767**

Founding Editors

Gerhard Goos
Juris Hartmanis

Editorial Board Members

Elisa Bertino, *Purdue University, West Lafayette, IN, USA*
Wen Gao, *Peking University, Beijing, China*
Bernhard Steffen, *TU Dortmund University, Dortmund, Germany*
Moti Yung, *Columbia University, New York, NY, USA*

The series Lecture Notes in Computer Science (LNCS), including its subseries Lecture Notes in Artificial Intelligence (LNAI) and Lecture Notes in Bioinformatics (LNBI), has established itself as a medium for the publication of new developments in computer science and information technology research, teaching, and education.

LNCS enjoys close cooperation with the computer science R & D community, the series counts many renowned academics among its volume editors and paper authors, and collaborates with prestigious societies. Its mission is to serve this international community by providing an invaluable service, mainly focused on the publication of conference and workshop proceedings and postproceedings. LNCS commenced publication in 1973.

Osvaldo Gervasi · Beniamino Murgante ·
Chiara Garau · Ana Maria A. C. Rocha ·
M. Noelia Faginas Lago · David Taniar ·
Yeliz Karaca
Editors

Computational Science and Its Applications – ICCSA 2026

26th International Conference
Braga, Portugal, June 30 – July 3, 2026
Proceedings, Part I

Springer

Editors
Osvaldo Gervasi
University of Perugia
Perugia, Italy

Chiara Garau
University of Cagliari
Cagliari, Italy

M. Noelia Faginas Lago
University of Perugia
Perugia, Italy

Yeliz Karaca
University of Massachusetts
Amherst, MA, USA

Beniamino Murgante
University of Basilicata
Potenza, Italy

Ana Maria A. C. Rocha
University of Minho
Braga, Portugal

David Taniar
Monash University
Melbourne, VIC, Australia

ISSN 0302-9743 ISSN 1611-3349 (electronic)
Lecture Notes in Computer Science
ISBN 978-3-032-30490-2 ISBN 978-3-032-30491-9 (eBook)
https://doi.org/10.1007/978-3-032-30491-9

© The Editor(s) (if applicable) and The Author(s), under exclusive license
to Springer Nature Switzerland AG 2027

This work is subject to copyright. All rights are solely and exclusively licensed by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed.
The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.
The publisher, the authors and the editors are safe to assume that the advice and information in this book are believed to be true and accurate at the date of publication. Neither the publisher nor the authors or the editors give a warranty, expressed or implied, with respect to the material contained herein or for any errors or omissions that may have been made. The publisher remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

If disposing of this product, please recycle the paper.

Preface

These 3 volumes (LNCS volumes 16767–16769) comprise the peer-reviewed papers from the 6 tracks of the 2026 International Conference on Computational Science and Its Applications (ICCSA 2026), held between June 30 and July 3, 2026, in Braga (Portugal). The peer-reviewed papers from the 57 Workshops are published in a separate set of 9 volumes (LNCS 16758–16766).

The conference was held in a hybrid format, with the vast majority of participants attending in person, hosted by the University of Minho in Braga, Portugal. We enabled virtual participation for those who did not attend the event in person due to logistical, political, or economic constraints by adopting a technological infrastructure based on open-source software (Jitsi + Riot) and a commercial Cloud infrastructure. ICCSA 2026 was organized by the University of Minho (Portugal), the University of Perugia (Italy), the University of Basilicata (Italy), the University of Cagliari (Italy), Monash University (Australia), and Kyushu Sangyo University (Japan).

With the 2026 edition, ICCSA celebrated its 26th anniversary, marking a new chapter in its longstanding history after its memorable 25th anniversary celebrated in Istanbul, Türkiye. Hosted in Braga, Portugal, the conference found a particularly meaningful setting in one of Europe's oldest and most vibrant academic cities, a place where historical depth, cultural continuity, and contemporary scientific exchange meet. Braga offers an inspiring European context for renewing the international and intercultural dialogue that has always characterized ICCSA, while giving new visibility to the role of computational science in addressing the complex challenges of cities, territories, technologies, and societies.

ICCSA 2026 marked another fruitful and thought-provoking academic event in the International Conferences on Computational Science and Its Applications (ICCSA) conference series, previously held in Istanbul, Türkiye (2025), Hanoi, Vietnam (2024), Athens, Greece (2023), Málaga, Spain (2022), Cagliari, Italy (hybrid with few participants in presence in 2021 and completely online in 2020), whilst earlier editions took place in Saint Petersburg, Russia (2019), Melbourne, Australia (2018), Trieste, Italy (2017), Beijing, China (2016), Banff, Canada (2015), Guimarães, Portugal (2014), Ho Chi Minh City, Vietnam (2013), Salvador, Brazil (2012), Santander, Spain (2011), Fukuoka, Japan (2010), Suwon, South Korea (2009), Perugia, Italy (2008), Kuala Lumpur, Malaysia (2007), Glasgow, UK (2006), Singapore (2005), Assisi, Italy (2004), Montreal, Canada (2003), and (as ICCS) Amsterdam, the Netherlands (2002) and San Francisco, USA (2001).

Computational Science constitutes the main pillar of most present research, industrial and commercial applications, and plays a unique role in exploiting innovative ICT technologies, and the ICCSA conference series has, accordingly, provided ample opportunities to researchers and industry practitioners to discuss new ideas, to share complex problems and their solutions, and to shape new trends in Computational Science. As the conference mirrors society from a scientific point of view, this year's undoubtedly

dominant theme was large language models, machine learning, and Artificial Intelligence (AI), and their applications across the most diverse technological, economic, and industrial fields, amongst others.

The ICCSA 2026 conference was structured into six general tracks covering computational science and its applications: Computational Methods, Algorithms and Scientific Applications; High-Performance Computing and Networks; Geometric Modelling, Graphics and Visualisation; Advanced and Emerging Applications; Information Systems and Technologies; and Urban and Regional Planning. In addition, the conference included 57 workshops, focusing on topical issues of utmost importance to science, technology, and society: from new computational approaches for earth science, to mathematical methods for image processing, new statistical and optimisation methods, several Artificial Intelligence approaches, sustainability issues, smart cities and related technologies, to name some.

In the Main Conference Proceedings, we accepted 119 full papers, 3 short papers and 2 Ph.D. Showcase papers on 405 submissions to the General Tracks of the Conference (with an acceptance rate of 29.9%). Reviews were single blind, and submissions received 2.6 reviews each, on average. In the Workshops proceedings, we accepted 321 full papers, 23 short papers and 3 Ph.D. Showcase papers from a total of 1184 submissions (Acceptance rate 29.9%). We would like to convey our sincere appreciation to the workshop chairs and co-chairs, and program committee members, for their diligent work, commitment, and dedication.

The success and consistent maintenance of the ICCSA conference series in general, and of ICCSA 2026 in particular, rely upon the support of many people: authors, presenters, participants, keynote speakers, workshop chairs, session chairs, Organizing Committee members, student volunteers, Program Committee members, Advisory Committee members, International Liaison chairs, reviewers, and other individuals in various roles. Thus, we take this opportunity to wholeheartedly thank each and every one.

We also wish to thank the publisher, Springer, for accepting the proceedings, for sponsoring part of the best paper awards, and for their kind assistance and cooperation during the editing process. We would cordially like to invite you to refer to the ICCSA website https://iccsa.org, where you can find the relevant details regarding this academic endeavour and our event.

June 2026

Chiara Garau
Ana Maria A. C. Rocha
Osvaldo Gervasi
Beniamino Murgante

Welcome Message from the Organizers

On behalf of the Local Organizing Committee of ICCSA 2026, it is our great pleasure to welcome you to the 26th International Conference on Computational Science and Its Applications, held from June 30 to July 3, 2026, at the University of Minho in Braga, Portugal.

We are deeply honoured by the trust placed in us by the ICCSA General Chairs in organizing another edition of this successful conference series. We hope that ICCSA 2026 provided an inspiring environment for scientific exchange, collaboration, and discussion among researchers from all over the world.

The conference took place at the University of Minho, one of the most prestigious higher education institutions in Portugal. Founded in 1973, the University of Minho has campuses in Braga and Guimarães and is widely recognized for its academic excellence, research activity, and strong international outlook.

Braga, one of the oldest cities in Portugal, is renowned for its historical heritage, cultural vitality, and welcoming atmosphere. Located in the heart of the Minho region, the city combines tradition with modernity, offering visitors renowned gastronomy, beautiful landscapes, and the unique character of *Vinho Verde* wine.

The scientific program of ICCSA 2026 included plenary lectures delivered by distinguished scientists, together with a broad range of workshops covering several areas of Computational Science and its Applications. We believe that the conference provided excellent opportunities to share ideas, discuss emerging challenges, and foster new collaborations.

In addition to the scientific sessions, participants had the opportunity to enjoy a rich social program. Planned activities included a Welcome Reception at Largo do Paço, the Rectorate of the University of Minho, located in the former Archbishop's Palace - one of the most emblematic historical buildings in the city center; a *Vinho Verde* wine tasting experience at Quinta d'Amares, where you can discover the art of winemaking; and a guided visit to the coastal city of Viana do Castelo, renowned for its maritime heritage, traditional architecture, and beautiful Atlantic scenery. The conference gala dinner took place at Colunata Eventos, located within the Bom Jesus do Monte sanctuary, a UNESCO World Heritage Site, where ICCSA participants enjoyed delicious recipes and a wonderful view over the city of Braga.

The success of ICCSA 2026 would not have been possible without the dedication and enthusiasm of many collaborators and volunteers, whose hard work and commitment greatly contributed to the organization of the conference. On behalf of the Local

Organizing Committee, it was our honour to warmly welcome you to the beautiful city of Braga and we hope you had an enjoyable and productive conference.

Sincerely yours,
On behalf of the Local Organizing Committee

Ana Maria A. C. Rocha

Organization

Honorary General Chairs

Bernady O. Apduhan	Kyushu Sangyo University, Japan
Kenneth C. J. Tan	Sardina Systems, UK

General Chairs

Ana Maria A. C. Rocha	University of Minho, Portugal
David Taniar	Monash University, Australia
Osvaldo Gervasi	University of Perugia, Italy

Program Committee Chairs

Beniamino Murgante	University of Basilicata, Italy
Chiara Garau	University of Cagliari, Italy

International Advisory Committee

Jemal Abawajy	Deakin University, Australia
Dharma P. Agarwal	University of Cincinnati, USA
Jagannath Aryal	University of Melbourne, Australia
Rajkumar Buyya	University of Melbourne, Australia
Claudia Bauzer Medeiros	University of Campinas, Brazil
Carl K. Chang	Iowa State University, USA
Elizabeth Chang	University of the Sunshine Coast, Australia
Manfred M. Fisher	Vienna University of Economics and Business, Austria
Pierre Frankhauser	University of Franche-Comté/CNRS, France
Marina L. Gavrilova	University of Calgary, Canada
Sumi Helal	University of Florida, USA & Lancaster University, UK
Bin Jiang	University of Gävle, Sweden
Yee Leung	Chinese University of Hong Kong, China
Biswajeet Pradhan	University of Technology Sydney, Australia
My Thai	University of Florida, USA

International Liaison Chairs

Giuseppe Borruso	University of Trieste, Italy
Elise De Donker	Western Michigan University, USA
Maria Noelia Faginas Lago	University of Perugia, Italy
Maria Irene Falcão	University of Minho, Portugal
Robert C. H. Hsu	Chung Hua University, Taiwan
Yeliz Karaca	UMass Chan Medical School, USA
Tae-Hoon Kim	Zhejiang University of Science and Technology, China
Vladimir Korkhov	Saint Petersburg University, Russia
Takashi Naka	Kyushu Sangyo University, Japan
Rafael D. C. Santos	National Institute for Space Research, Brazil
Maribel Yasmina Santos	University of Minho, Portugal
Anastasia Stratigea	National Technical University of Athens, Greece
Nguyen Canh Thai	Thuyloi University, Vietnam
Kh Md Nahiduzzaman	Mohammed VI Polytechnic University, Rabat, Morocco

Workshop and Session Organizing Chairs

Beniamino Murgante	University of Basilicata, Italy
Chiara Garau	University of Cagliari, Italy

Award Chair

Wenny Rahayu	La Trobe University, Australia

Publicity Committee Chairs

Elmer Dadios	De La Salle University, Philippines
Nataliia Kulabukhova	Saint Petersburg University, Russia
Daisuke Takahashi	Tsukuba University, Japan
Doan Quang Tu	Academy of Military Science and Technology, Vietnam
Shangwang Wang	Beijing University of Posts and Telecommunications, China

Local Organizing Committee Chairs

Maria Irene Falcão	University of Minho, Portugal
Ana Cristina Braga	University of Minho, Portugal
Rui José	University of Minho, Portugal
José Manuel Machado	University of Minho, Portugal
Jorge G. Rocha	University of Minho, Portugal

Technology Chair

Damiano Perri	University of Perugia, Italy

Program Committee

Vera Afreixo	University of Aveiro, Portugal
Vladimir Alarcon	Northern Gulf Institute, USA
Filipe Alvelos	University of Minho, Portugal
Debora Anelli	Polytechnic University of Bari, Italy
Muhammad Waqas Arshad	University of Bologna, Italy
Vittorio Astarita	University of Calabria, Italy
Hartmut Asche	Hasso-Plattner-Institut für Digital Engineering Ggmbh, Germany
Nizamettin Aydın	İstanbul Technical University, Türkiye
Ginevra Balletto	University of Cagliari, Italy
Nadia Balucani	University of Perugia, Italy
Socrates Basbas	Aristotle University of Thessaloniki, Greece
David Berti	ART SpA, Italy
Sandro Bimonte	CEMAGREF, TSCF, France
Ana Cristina Braga	University of Minho, Portugal
Tiziana Campisi	University of Enna KORE, Italy
Alessandra Capolupo	Polytechnic of Bari, Italy
Leocadio G. Casado	University of Almeria, Spain
Ilaria Catapano	National Research Council, IREA, Italy
Maria Cerreta	University of Naples Federico II, Italy
Rachel Chien-Sing Lee	Sunway University, Malaysia
Birol Ciloglugil	Ege University, Turkey
Florbela Maria da Cruz Domingues Correia	Polytechnic Institute of Viana do Castelo, Portugal
Alessandro Costantini	INFN, Italy
Roberto De Lotto	University of Pavia, Italy
Luiza De Macedo Mourelle	State University of Rio De Janeiro, Brazil

Marcelo De Paiva Guimaraes	Federal University of São Paulo, Brazil
Marco De Santis	University of Salerno, Italy
Frank Devai	London South Bank University, UK
Joana Matos Dias	University of Coimbra, Portugal
Aziz Dursun	Virginia Tech University, USA
Laila El Ghandour	Heriot Watt University, UK
Maria Irene Falcão	University of Minho, Portugal
Florbela P. Fernandes	Polytechnic Institute of Bragança, Portugal
Paula Odete Fernandes	Polytechnic Institute of Bragança, Portugal
Adelaide de Fátima Baptista Valente Freitas	University of Aveiro, Portugal
Andreas Fricke	University of Potsdam, Germany
Raffaele Garrisi	Centro Operativo per la Sicurezza Cibernetica, Italy
Ivan Gerace	University of Perugia, Italy
Maria Giaoutzi	National Technical University of Athens, Greece
Salvatore Giuffrida	University of Catania, Italy
Teresa Guarda	Universidad Estatal Península de Santa Elena, Ecuador
Gabriel Guerrero Contreras	University of Cádiz, Spain
Malgorzata Hanzl	Technical University of Lodz, Poland
Maulana Adhinugraha Kiki	Telkom University, Indonesia
JungYoon Kim	Gachon University, South Korea
Clement Ho Cheung Leung	Chinese University of Hong Kong, China
Andrea Lombardi	University of Perugia, Italy
Marcos Mandado Alonso	University of Vigo, Spain
Ernesto Marcheggiani	Katholieke Universiteit Leuven, Belgium
Barbara Martelli	INFN, Italy
Antonino Marvuglia	Luxembourg Institute of Science and Technology, Luxembourg
Michele Mastroianni	University of Salerno, Italy
Hideo Matsufuru	High Energy Accelerator Research Organization, Japan
Fernando Miranda	Universidade do Minho, Portugal
Giuseppe Modica	University of Reggio Calabria, Italy
Majaz Moonis	UMass Chan Medical School, USA
Leila Moradi	University of Salerno, Italy
Nadia Nedjah	State University of Rio de Janeiro, Brazil
Paolo Nesi	University of Florence, Italy
Suzan Obaiys	University of Malaya, Malaysia
Marcin Paprzycki	Polish Academy of Sciences, Poland
Eric Pardede	La Trobe University, Australia

Ana Isabel Pereira	Polytechnic Institute of Bragança, Portugal
Damiano Perri	University of Perugia, Italy
Massimiliano Petri	University of Pisa, Italy
Telmo Pinto	University of Coimbra, Portugal
Maurizio Pollino	ENEA, Italy
Marcos Quiles	Federal University of São Paulo, Brazil
Nguyen Huu Quynh	Thuyloi University, Vietnam
Albert Rimola	Universitat Autònoma de Barcelona, Spain
Humberto Rocha	University of Coimbra, Portugal
Marzio Rosi	University of Perugia, Italy
Lucia Saganeiti	University of L'Aquila, Italy
Francesco Scorza	University of Basilicata, Italy
Marco Paulo Seabra dos Reis	University of Coimbra, Portugal
Jie Shen	University of Michigan, USA
Bruno Sousa	University of Coimbra, Portugal
Francesco Tajani	Sapienza University of Rome, Italy
Daniela Tavano	University of Calabria, Italy
Ho Sy Tam	Thuyloi University, Vietnam
Deodato Tapete	Italian Space Agency ASI, Italy
Rodrigo Tapia-McClung	Centro de Investigación en Ciencias de Información Geoespacial, Mexico
Tarek Teba	University of Portsmouth, UK
Ana Paula Teixeira	Universidade do Minho, Portugal
Luis Teodoro	University of Oslo, Norway
Yiota Theodora	National Technical University of Athens, Greece
Elena Todella	Polytechnic University of Turin, Italy
Graca Tomaz	Instituto Politécnico da Guarda, Portugal
Anna Tonazzini	National Research Council, Italy
Francesca Torrieri	Polytechnic University of Milan, Italy
Vincenza Torrisi	University of Catania, Italy
Vincenzo Totaro	Polytechnic University of Bari, Italy
Arianna Travaglini	University of Basilicata, Italy
Stefanos Tsigdinos	National Technical University of Athens, Greece
Aime Tsinda	University of Rwanda, Rwanda
Elen Twrdy	University of Ljubljana, Slovenia
Doan Quang Tu	Academy of Military Science and Technology, Vietnam
Le Quang Tuan	Thuyloi University, Vietnam
Toshihiro Uchibayashi	Kyushu University, Japan
Fukuko Yuasa	High Energy Accelerator Research Organization, Japan
Ljiljana Zivkovic	Republic Geodetic Authority, Serbia

Workshop on Advancements in Applied Machine-Learning and Data Analytics (AAMDA 2026)

Workshop Organizers:

Alessandro Costantini	INFN, Italy
Elisabetta Ronchieri	INFN CNAF, Italy

Artificial Intelligence Tools In Managing Future Communities (AiMFutCOM 2026)

Workshop Organizers:

Marco Vona	University of Basilicata, Italy
Francesco Scorza	University of Basilicata, Italy
Donatello Cardone	University of Basilicata, Italy
Maurizio Pollino	ENEA, Italy
Gregorio DAgostino	ENEA, Italy

Advanced and Innovative Web Apps 2026 (AIWA 2026)

Workshop Organizers:

Damiano Perri	University of Perugia, Italy
Osvaldo Gervasi	University of Perugia, Italy
Luciano Alessandro Ipsaro Palesi	University of Florence, Italy

Advanced Mathematics and Computing Models in Complex Data-Intensive Computational Systems (AMCM 2026)

Workshop Organizers:

Yeliz Karaca	UMass Chan Medical School and Massachusetts Institute of Technology, USA
Dumitru Baleanu	Lebanese American University, Lebanon
Osvaldo Gervasi	University of Perugia, Italy
Yudong Zhang	University of Leicester, UK
Majaz Moonis	UMass Chan Medical School, USA

Advanced Numerical Approaches for Assessment and Design of No-Tension Masonry Structures (ANAMS 2026)

Workshop Organizers:

Antonino Iannuzzo	Universitá degli studi del Sannio, Italy
Natalia Pingaro	Politecnico di Milano, Italy
Andrea Montanino	International Centre for Numerical Methods in Engineering, Spain
Elham Mousavian	University of Edinburgh, UK
Stefano Galassi	University of Florence, Italy

Artificialization of land, Urban Transformation, and Territorial Resilience in a Changing Climate (AUTTREC 2026)

Workshop Organizers:

Celestina Fazia	Università di Enna Kore, Italy
Kh Md Nahiduzzaman	Mohammed VI Polytechnic University, Morocco
Hassan Radoine	Mohammed VI Polytechnic University, Morocco
Cezar Morar	University of Oradea, Romania
Antonio García Martínez	Universidad de Sevilla, Spain
Clara Stella Vicari Aversa	Università degli Studi Mediterranea di Reggio Calabria, Italy

Blockchain and Distributed Ledgers: Technologies and Applications (BDLTA 2026)

Workshop Organizers:

Vladimir Korkhov	Saint Petersburg State University, Russia
Elena Stankova	Saint Petersburg State University, Russia
Nataliia Kulabukhova	AutoTech, Russia

Bio and Neuro inspired Computing and Applications (BIONCA 2026)

Workshop Organizers:

Nadia Nedjah	State University of Rio de Janeiro, Brazil
Luiza de Macedo Mourelle	State University de Rio de Janeiro, Brazil

Computational and Applied Mathematics (CAM 2026)

Workshop Organizers:

Maria Irene Falcao	University of Minho, Portugal
Fernando Miranda	Universidade do Minho, Portugal

Computational and Applied Statistics for Data and AI (CAS 2026)

Workshop Organizers:

Ana Cristina Braga	University of Minho, Portugal
Ines Sena	University of Minho, Portugal
Joao Mendes	Polytechnic Institute of Bragança, Portugal

Circular Economy and Territorial Competitiveness (CETC 2026)

Workshop Organizers:

Gerardo Carpentieri	University of Naples Federico II, Italy
Carmen Guida	Università degli Studi di Napoli Federico II, Italy
Floriana Zucaro	University of Naples Federico II, Italy
Zhadyra Konurbaeva	D. Serikbayev East Kazakhstan Technical University, Kazakhstan
Saule Kumargazhanova	D.Serikbayev East Kazakhstan Technical University, Kazakhstan

Circular Ecological Heritage Communities: Regeneration and Evaluation Strategies for Historic Villages, Landscapes and Rural Territories (CHEC 2026)

Workshop Organizers:

Mariarosaria Angrisano	Pegaso University, Italy
Antonia Gravagnuolo	CNR Institute of Heritage Science, Italy
Francesca Buglione	CNR ISPC, Italy
Piera Della Morte	Pegaso Telematic University, Italy

Cyber Intelligence and Applications (CIA 2026)

Workshop Organizers:

Gianni DAngelo	University of Salerno, Italy
Francesco Palmieri	University of Salerno, Italy
Massimo Ficco	University of Salerno, Italy

Computational Methods, Statistics and Industrial Mathematics (CMSIM 2026)

Workshop Organizers:

Maria Filomena Teodoro	CINAV, Escola Naval, Instituto Universitário Militar, Portugal
Paula Simões	Academia Militar, Portugal
Teresa A. Oliveira	University of Lisbon and Universidade Aberta, Portugal

Computational Optimization and Applications (COA 2026)

Workshop Organizers:

Ana Maria A. C. Rocha	University of Minho, Portugal
Humberto Rocha	University of Coimbra, Portugal

Computational Methods in Advanced Networking Technologies (CoMANT 2026)

Workshop Organizers:

Eslam Farsimadan	University of Salerno, Italy
Leila Moradi	University of Salerno, Italy
Francesco Palmieri	University of Salerno, Italy

Computational Astrochemistry 2026 (CompAstro 2026)

Workshop Organizers:

Marzio Rosi	University of Perugia, Italy
Daniela Ascenzi	Università degli Studi di Trento, Italy
Nadia Balucani	University of Perugia, Italy
Stefano Falcinelli	University of Perugia, Italy

Computational Methods for Porous Materials (CompPor 2026)

Workshop Organizers:

Vadim Lisitsa	Institute of Petroleum Geology and Geophysics SB RAS, Russia
Evgeniy Romenski	Sobolev Institute of Mathematics, Russia

Workshop on Computational Science and HPC (CSHPC 2026)

Workshop Organizers:

Elise de Doncker	Western Michigan University, USA
Hideo Matsufuru	High Energy Accelerator Research Organization, Japan
Robert Makin	Western Michigan University, USA

Cities, Technologies and Planning (CTP 2026)

Workshop Organizers:

Giuseppe Borruso	University of Trieste, Italy
Beniamino Murgante	University of Basilicata, Italy
Malgorzata Hanzl	Lodz University of Technology, Poland
Anastasia Stratigea	National Technical University of Athens, Greece
Ljiljana Zivkovic	Republic Geodetic Authority, Serbia
Ginevra Balletto	University of Cagliari, Italy

Evaluating Inner Areas Potentials (EIAP 2026)

Workshop Organizers:

Diana Rolando	Politecnico di Torino, Italy
Manuela Rebaudengo	Politecnico di Torino, Italy
Alice Barreca	Politecnico di Torino, Italy
Giorgia Malavasi	Politecnico di Torino, Italy

sustainablE mobiLity and Last mIle lOgisTic in Urban Context (ELLIOT 2026)

Workshop Organizers:

Tiziana Campisi	University of Enna Kore, Italy
Socrates Basbas	Aristotle University of Thessaloniki, Greece
Florin Rusca	National University of Science and Technology Politehnica Bucharest, Romania
Grigorios Fountas	Aristotle University of Thessaloniki, Greece
Aleksandra Deluka-Tibljas	University of Rijeka, Croatia

Econometrics and Multidimensional Evaluation in Urban Environment (EMEUE 2026)

Workshop Organizers:

Maria Cerreta	University of Naples Federico II, Italy
Giuseppe Ciciriello	University of Naples Federico II, Italy
Simona Panaro	University of Sussex Business School, UK
Piero Zizzania	Università of Naples Federico II, Italy
Pierluigi Morano	Polytechnic University of Bari, Italy
F rancesco Tajani	Sapienza University of Rome, Italy

Ecosystem Services in Spacial Planning for Climate Neutral Urban and Rural Areas (ESSP 2026)

Workshop Organizers:

Sabrina Lai	University of Cagliari. Italy
Carmela Gargiulo	Università Federico II di Napoli, Italy
Beniamino Murgante	University of Basilicata, Italy
Francesco Scorza	University of Basilicata, Italy
Corrado Zoppi	University of Cagliari, Italy
Floriana Zucaro	University of Naples Federico II, Italy

The 16th International Workshop on Future Information System Technologies and Applications (FiSTA 2026)

Workshop Organizers:

Bernady O. Apduhan	Kyushu Sangyo University, Japan
Rafael Santos	National Institute for Space Research (INPE), Brazil

Geographical Analysis, Urban Modeling, Spatial Statistics (Geog-And-Mod 2026)

Workshop Organizers:

Giuseppe Borruso	University of Trieste, Italy
Beniamino Murgante	University of Basilicata, Italy
Hartmut Asche	Hasso Plattner Institute for Digital Engineering, Germany
Rodrigo Tapia McClung	Centro de Investigación en Ciencias de Información Geoespacial, Mexico
Andreas Fricke	Hasso Plattner Institute for Digital Engineering, University of Potsdam, Germany

Generative and Neuro-Symbolic Artificial Intelligence for Real-World Systems (GNS-AI 2026)

Workshop Organizers:

Hugo Peixoto	University of Minho, Portugal
Manuel Rodrigues	University of Minho, Portugal
Regina Sousa	University of Minho, Portugal

Geomatics for Resource Monitoring and Management (GRMM 2026)

Workshop Organizers:

Alberico Sonnessa	Politecnico di Bari, Italy
Eufemia Tarantino	Politecnico di Bari, Italy
Marco Locurcio	Polytechnic University of Bari, Italy

International Workshop on Information and Knowledge in the Internet of Things (IKIT 2026)

Workshop Organizers:

Teresa Guarda	Universidad Estatal Península de Santa Elena, Ecuador

Intelligent Sustainable Development: from Models to Real-World Impact (ISD 2026)

Workshop Organizers:

Diego Brandão (	Federal Center for Technological Education of Rio de Janeiro, Brazil
Angela Ferreira	Polytechnic University of Bragança, Portugal
Eduardo Bezerra	Federal Center for Technological Education of Rio de Janeiro, Brazil
Raphael Guerra	Universidade Federal Fluminense, Brazil
Douglas Cardoso	University of Coimbra, Portugal
Rui Pedro Lopes	Polytechnic Institute of Bragança, Portugal

Multidimensional Evolutionary Evaluations for Transformative Approaches (MEETA 2026)

Workshop Organizers:

Maria Cerreta	University of Naples Federico II, Italy
Giuliano Poli	Università Federico II di Napoli, Italy
Gaia Daldanise	CNR Institute for Research on Innovation and Services for Development, Italy
Ludovica La Rocca	University of Federico II of Naples, Italy
Maria Somma	University of Naples Federico II, Italy
Sabrina Sacco	University of Naples Federico II, Italy

Building Multi-dimensional Models for Assessing Complex Environmental Systems (MES 2026)

Workshop Organizers:

Vanessa Assumma	University of Bologna, Italy
Caterina Caprioli	Politecnico di Torino, Italy
Giulia Datola	Politecnico di Milano, Italy

Federico DellAnna	Politecnico di Torino, Italy
Marta DellOvo	Politecnico di Milano, Italy
Marco Rossitti	Politecnico di Milano, Italy

Computational Mechanics, Intelligence, and Data (MIND 2026)

Workshop Organizers:

Lelio Campanile	Università degli Studi della Campania Luigi Vanvitelli, Italy
Renato Zona	Università della Campania Vanvitelli, Italy

Modelling Liveable Cities: Techniques, Methods, Challenges, and Perspectives Behind the X-Minute City (MLC 2026)

Workshop Organizers:

Federico Mara	University of Pisa, Italy
Valerio Cutini	University of Pisa, Italy

Mathematical Methods for Image Processing and Understanding 2026 (MMIPU 2026)

Workshop Organizers:

Ivan Gerace	Università degli Studi di Perugia, Italy
Gianluca Vinti	Università degli Studi di Perugia, Italy
Arianna Travaglini	Lucian Blaga University of Sibiu, Romania

MOdels and Indicators for Assessing and Measuring the Urban Settlement deVElopment in the View of NET ZERO by 2050 (MOVEto0 2026)

Workshop Organizers:

Lorena Fiorini	University of L'Aquila, Italy
Lucia Saganeiti	Institute of Methodologies for Environmental Analysis (IMAA) CNR, Italy
Angela Pilogallo	Institute of Methodologies for Environmental Analysis (IMAA), Italy
Francesco Zullo	University of L'Aquila, Italy
Alessandro Marucci	University of L'Aquila, Italy

Numerical Aspects in Machine Learning for Dynamical Systems (NAMLYS 2026)

Workshop Organizers:

Pasquale De Luca	Parthenope University of Naples, Italy
Livia Marcellino	University of Naples Parthenope, Italy
Valeria Mele	University of Naples Federico II, Italy

Numerical Methods and Machine Learning in Science and Engineering (NMLSE 2026)

Workshop Organizers:

Cecília Coelho	Helmut Schmidt University, Germany
M. Fernanda P. Costa	University of Minho, Portugal
Luís Ferrás	University of Minho, Portugal
Eliana Costa e Silva	Polytechnic of Porto, Portugal

6th Workshop on Privacy in the Cloud/Edge/IoT World 2026 (PCEIoT 2026)

Workshop Organizers:

Lelio Campanile	Università degli Studi della Campania Luigi Vanvitelli, Italy
Mauro Iacono	Università degli Studi della Campania Luigi Vanvitelli, Italy
Michele Mastroianni	University of Foggia, Italy

Preserving Our Past: Spatial and Remote Sensing Technologies for Cultural Heritage in a Changing Climate (POP 2026)

Workshop Organizers:

Maria Danese	Institute of Heritage Science of the National Research Council of Italy (CNR ISPC), Italy
Rosa Lasaponara	Institute of Methodologies for Environmental Analysis (CNR IMAA), Italy
Nicola Masini	Institute of Heritage Science of the National Research Council of Italy (CNR ISPC), Italy

Scientific Computing Infrastructure (SCI 2026)

Workshop Organizers:

Vladimir Korkhov	Saint Petersburg State University, Russia
Elena Stankova	Saint Petersburg State University, Russia

Socio-Economic and Environmental Models for Land Use Management (SEMLUM 2026)

Workshop Organizers:

Debora Anelli	Sapienza University of Rome, Italy
Pierluigi Morano	Polytechnic University of Bari, Italy
Francesco Tajani	Sapienza University of Rome, Italy
Felicia Di Liddo	Polytechnic University of Bari, Italy

Ports and Logistics of the Future - Smartness and Sustainability (SmartPorts 2026)

Workshop Organizers:

Andrea Gallo	Università degli Studi di Trieste, Italy
Giuseppe Borruso	University of Trieste, Italy
Gianfranco Fancello	University of Cagliari, Italy
Veronica Camerada	Università degli studi di Sassari, Italy
Clara Di Fazio	University of Trieste, Italy

Sustainable Evolution of Long-Distance frEight and paSsenger Transport (SOLIDEST 2026)

Workshop Organizers:

Antonio Russo	University of Enna Kore, Italy
Giuseppe Musolino	Università Mediterranea di Reggio Calabria, Italy
Socrates Basbas	Aristotle University of Thessaloniki, Greece
Oana Dinu	National University of Science and Technology Politehnica Bucharest, Romania
Sanja Šurdonja	University of Rijeka, Croatia
Elen Twrdy	University of Ljubljana, Slovenia

Sustainability Performance Assessment: Models, Approaches, and Applications Toward Interdisciplinary and Integrated Solutions. (SPA 2026)

Workshop Organizers:

Francesco Scorza	University of Basilicata, Italy
Sabrina Lai	University of Cagliari, Italy
Jolanta Dvarioniene	Kaunas University of Technology, Lithuania
Michele Campagna	University of Cagliari, Italy

Specifics of Smart Cities Development in Europe (SPEED 2026)

Workshop Organizers:

Chiara Garau	University of Cagliari, Italy
Katarína Vitálišová	Matej Bel University, Slovak Republic
Marco Fanfani	University of Florence, Italy
Anna Vaňová	Matej Bel University, Slovak Republic
Kamila Borsekova	Matej Bel University, Slovak Republic
Paola Zamperlin	University of Pisa, Italy

Smart, Safe, and Health Cities (SSHC 2026)

Workshop Organizers:

Chiara Garau	University of Cagliari, Italy
Gerardo Carpentieri	University of Naples Federico II, Italy
Carmen Guida	Università degli Studi di Napoli Federico II, Italy
Martina Carra	University of Brescia, Italy
Vincenza Torrisi	University of Catania, Italy
Silvia Rossetti	Università degli Studi di Parma, Italy

Smart and Sustainable Island Communities (SSIC 2026)

Workshop Organizers:

Chiara Garau	University of Cagliari, Italy
Anastasia Stratigea	National Technical University of Athens, Greece
Yiota Theodora	National Technical University of Athens, Greece
Giovanna Concu	University of Cagliari, Italy
Tiziana Campisi	University of Enna Kore, Italy
Tanja Congiu	University of Sassari, Italy

Sustainable Tourism Economy, Silk Road, Reuse and Enhancement of Cultural Heritage (STESilkRoad 2026)

Workshop Organizers:

Celestina Fazia	Università di Enna Kore, Italy
Alexandru Ilies	University of Oradea, Romania
Dorina Camelia Ilies	University of Oradea, Romania
Cristina Natoli	Ministero dell'Ambiente e della Sicurezza Energetica, Italy
Bahodirhon Safarov	Samarkand Branch of Tashkent State University of Economics, Uzbekistan
Clara Stella Vicari Aversa	Università degli Studi Mediterranea di Reggio Calabria, Italy

Theoretical and Computational Chemistry and its Applications (TCCM 2026)

Workshop Organizers:

Noelia Faginas Lago	Università di Perugia, Italy
Andrea Lombardi	Università di Perugia, Italy
Marcos Mandado Alonso	University of Vigo, Spain

Transport Infrastructures for Smart Cities (TISC 2026)

Workshop Organizers:

Francesca Maltinti	University of Cagliari, Italy
Mauro Coni	University of Cagliari, Italy
Chiara Garau	University of Cagliari, Italy
Benedetto Barabino	University of Brescia, Italy
Nicoletta Rassu	Università di Cagliari, Italy
James Rombi	University of Cagliari, Italy

Transforming Urban Analytics: The Impact of Crowdsourced Mapping and Advanced AI Techniques on Future Cities (Tr-UrbAna 2026)

Workshop Organizers:

Ayse Giz Gulnerman Gengec	Ankara Hacı Bayram Veli University, Turkey
Müslüm Hacar	Yildiz Technical University, Turkey

From Structural to TRAnsformative-Change of City Environment: Challenges and Solutions and Perspectives (TRACE 2026)

Workshop Organizers:

Maria Rosaria Guarini	Sapienza University of Rome, Italy
Pierluigi Morano	Polytechnic University of Bari, Italy
Francesco Sica	Sapienza University of Rome, Italy
Alejandro Segura	Universidad Politécnica de Madrid, Spain
Yilsy María Nuñez Guerrero	Universidad Politécnica de Madrid, Spain

Urban Artificial Intelligence for Modelling, Analysis and Planning (Urban plAnnIng 2026)

Workshop Organizers:

Chiara Garau	University of Cagliari, Italy
Romano Fistola	University of Naples Federico II, Italy
Beniamino Murgante	University of Basilicata, Italy
Dessislava Petrova Antonova	Sofia University, GATE Institute, Bulgaria
Gianni Pantaleo	University of Florence, Italy
Rosa Anna La Rocca	University of Naples Federico II, Italy

Urban Space Accessibility and Mobilities (USAM 2026)

Workshop Organizers:

Chiara Garau	University of Cagliari, Italy
Alessandro Plaisant	University of Sassari, Italy
Barbara Caselli	Università degli Studi di Parma, Italy
Mauro D. Apuzzo	University of Cassino and Southern Lazio, Italy
Francesco Pinna	University of Cagliari, Italy
Silvio Nocera	IUAV University of Venice, Italy

Virtual Reality, Augmented Reality and Applications (VRA 2026)

Workshop Organizers:

Damiano Perri	University of Perugia, Italy
Osvaldo Gervasi	University of Perugia, Italy
Paolo Nesi	University of Florence, Italy

Workshop on Advanced and Computational Methods for Earth Science Applications (WACM4ES 2026)

Workshop Organizers:

Luca Piroddi	University of Cagliari, Italy
Patrizia Capizzi	University of Palermo, Italy
Marilena Cozzolino	Università del Molise, Italy
Giuseppina Vacca	University of Cagliari, Italy
Luigi Capozzoli	Hydrogeosite Laboratory of CNR-IMAA, Italy
Nikos Papadopoulos	Foundation for Research and Technology Hellas, Greece

Sponsoring Organizations

ICCSA 2026 would not have been possible without the tremendous support of many organizations and institutions, for which all organizers and participants of ICCSA 2026 express their sincere gratitude:



Universidade do Minho
Escola de Engenharia

University of Minho, Portugal (https://www.uminho.pt/)



University of Perugia, Italy (https://www.unipg.it)



University of Basilicata, Italy (http://www.unibas.it)



University of Cagliari, Italy (https://unica.it/)



Monash University, Australia (https://www.monash.edu/)



Kyushu Sangyo University, Japan (https://www.kyusan-u.ac.jp/)

Venue

ICCSA 2026 took place at:
the University of Minho campus:
Campus de Gualtar
4710-057 Braga
Portugal





Plenary Lectures

Digital Twins for Cities – The Rise of the Socio-Technical System

Claudia van der Laag

Professor of Urban Analytics, Department of Built Environment, Oslo Metropolitan University, Oslo

Abstract. Cities are entering a new era in which digital twins are no longer simply technical replicas of urban systems, but evolving socio-technical infrastructures that shape how cities are planned, governed, and experienced. Across the world, urban digital twins are being adopted to address some of the most pressing challenges of our time—climate adaptation, urban resilience, mobility transitions, decarbonisation, infrastructure management, and inclusive governance. Yet as these technologies become increasingly sophisticated, a fundamental question emerges: can digital twins truly support more democratic and human-centred cities, or will they reinforce existing structures of power and expertise? In this keynote, Claudia van der Laag, explores the transformation of urban digital twins from data-driven modelling tools into collaborative platforms for urban decision-making and societal change. It argues that the future of digital twins lies not only in advances in artificial intelligence, real-time data integration, simulation, and predictive analytics, but equally in the ability to connect technological innovation with governance, participation, and human agency. Drawing on emerging international research and practical case studies, the keynote examines the complex ecosystem surrounding urban digital twins, bringing together planners, policymakers, researchers, technologists, and communities. It highlights how digital twins increasingly function as meeting points between multiple forms of knowledge—technical, political, social, and experiential—and why interdisciplinary collaboration is essential for their success. The talk will critically reflect on the tensions between technological ambition and civic inclusion, exploring themes such as transparency, interoperability, participation, and trust. It will also discuss how digital twins can become powerful environments for scenario exploration, urban experimentation, and collective learning, enabling cities to better navigate uncertainty and complexity in an age of rapid urban transformation. Ultimately, this keynote presents a vision of digital twins not as neutral technological systems, but as living socio-technical infrastructures capable of reshaping urban governance itself. The challenge ahead is therefore not only how accurately cities can be modelled, but how inclusively they can be imagined, negotiated, and governed through these emerging digital environments.

Short Bio – Claudia van der Laag (also known as Claudia Yamu) is Professor of Urban Analytics at Oslo Metropolitan University. Her work advances urban analytics and spatial modelling through an integrated multi-method approach, informing sustainable urban planning and policy. She is widely recognised for bridging theory and practice and received the prestigious Michael Breheny Prize for her contributions to multi-scale

modelling. Van der Laag is co-author of the widely recognised textbook ‘Introduction to Space Syntax in Urban Studies’. She also serves on the editorial advisory board of Springer’s The Urban Book Series and the journal Environment and Planning B: Urban Analytics and City Science.

Prescriptive AI in Practice: Bridging Optimisation, Generative AI and Agentic Decision-Making

Bernardo Almada-Lobo

Universidade do Porto, Faculdade de Engenharia, INESC TEC, Portugal

Abstract. Prescriptive AI, viewed through the lens of mathematical optimisation and operations research, addresses complex business decision-making problems involving limited resources, multiple decision options and competing objectives. This talk considers the full decision pipeline: problem framing, model formulation, computational solution, implementation, monitoring and organisational adoption. The practical success of prescriptive AI depends less on algorithmic sophistication alone than on the quality of the translation between real-world decision contexts and formal optimisation models. In practice, this translation remains a major bottleneck. Objectives are often ambiguous, constraints are incomplete or tacit, data may be fragmented, and the operational consequences of a recommendation may be poorly understood. As a result, optimisation projects can fail even when the underlying mathematical model is technically sound. The talk will address the persistent gap between optimisation theory and deployment practice. While optimisation has generated substantial value in domains such as supply chain planning, logistics, production, revenue management, workforce planning and inventory control, many initiatives still face a significant risk of under-delivery. Common failure modes include incorrect problem framing, weak data readiness, brittle assumptions, infeasible or non-actionable recommendations, limited explainability, insufficient ownership by business users and inadequate post-deployment monitoring. Crossing this gap requires moving from one-off model building to an operational lifecycle in which models are stress-tested, embedded in workflows, monitored for drift and revised as the business environment changes. Recent developments in generative and agentic AI create new opportunities to reduce these barriers. Generative AI can support the elicitation of decision-maker preferences, the structuring of unstructured operational knowledge, the drafting of candidate formulations and the explanation of model outputs in business language. Agentic AI can extend this role by orchestrating multi-step workflows that involve model formulation, solver-code generation, execution, debugging, infeasibility diagnosis, sensitivity analysis and human review. However, these capabilities should not be interpreted as replacing optimisation expertise. Rather, they create a new interface between human judgement, analytical modelling and computational decision support. This talk will discuss a cross-fertilisation agenda between optimisation, generative AI and agentic AI, with a focus on how these technologies should be calibrated to the decision at hand.

Short Bio – Full Professor of Industrial Engineering and Management at the Faculty of Engineering of University of Porto (FEUP). Co-founder and Partner at LTPlabs, a Business AI company. Member of the Board of Trustees of the Belmiro de Azevedo

Foundation. Member of the Academy of Engineering. Former Board Member of INESC TEC and Researcher at the MIT Sloan School of Management. Holds a BEng, PhD and Habilitation in Industrial Engineering and Management from FEUP. Completed the Advanced Management Programme at INSEAD, and the Mergers and Acquisitions at London Business School. Certified Analytics Professional (CAP) by INFORMS. His area of activity is Business Analytics and Artificial Intelligence. He researches, develops and implements analytical models and methods to support decision-making, solving management problems across various domains—manufacturing, consumer goods, retail and transport—with a particular focus on Operations Management and the Operations–Marketing interface. He has coordinated and participated in more than 300 development, consultancy and research projects funded by private organisations, science agencies from several countries, the European Commission and regional bodies. He has published more than 100 scientific articles and is co-author of the book Analytics Sandwich: Bringing People and Artificial Intelligence Together to Unlock Business Value. He has supervised more than 20 doctoral theses.

Net-Zero Communities Through Life Cycle Thinking: Canadian Lessons and Global Implications

Kasun Hewage

Professor of Engineering, School of Engineering (Okanagan Campus), The University of British Columbia (UBC), Canada, FortisBC Smart Energy Chair, Associate Director, Clean Energy Research Centre (CERC)

Abstract. This keynote presentation discusses how life cycle thinking supports the transformation of communities toward sustainable, resilient, and net-zero futures. Drawing on Canadian research, practice, and policy experience, the presentation highlights how integrated life cycle approaches can move beyond conventional carbon accounting to inform practical decision-making across buildings, infrastructure, energy systems, waste management, water systems, and industrial processes [1-8]. The keynote features research conducted at the Life Cycle Management Laboratory (LCML) at the University of British Columbia, Canada, an internationally recognized research hub led by Prof. Kasun Hewage. LCML brings together engineers, scientists, policy researchers, postdoctoral fellows, visiting scholars, and graduate researchers to translate data-intensive sustainability research into actionable climate solutions. The laboratory's work is organized around six interconnected research themes: energy systems, urban development, water systems, waste management, construction and asset management, and industrial processes and products. Together, these themes provide an integrated platform for advancing life cycle–based pathways to net-zero communities. Supported by strong partnerships with government, industry, and community stakeholders, LCML has contributed to a substantial body of applied sustainability research, including more than 400 journal articles, 100 conference papers, and numerous technical reports that have informed real-world planning and implementation. This keynote presentation highlights selected success stories that demonstrate how life cycle thinking can be translated into practical strategies for reducing environmental impacts while strengthening community resilience. These insights are especially relevant to the interdisciplinary focus of ICCSA 2026, which will be held in collaboration with the University of Minho in Braga, Portugal, from June 30 to July 3, 2026.

References

1. Weerasinghe, O., Hewage, K., Razi, F., Fatmi, M., Sadiq, R.: Applicability of land use models for sustainable urban planning: a review. J. Urban Plann. Dev. ASCE (2025). Accepted 3 Marc 2025

2. Sultana, S.R., et al.: Looking beyond energy efficiency targets: life cycle sustainability of mechanical and water heating equipment in Canadian homes. J. Clean. Prod. **473**, 143469 (2024). https://doi.org/10.1016/j.jclepro.2024.143469
3. Liyanage D.R., Hewage K., Hussain S.H., Razi F., Sadiq R.: Climate adaptation of existing buildings: a critical review on planning energy retrofit strategies for future climate. Renew. Sustain. Energy Rev. **199**, 114476 (2024). https://doi.org/10.1016/j.rser.2024.114476
4. Liyanage D.R., Hewage K., Karunathilake H., Sadiq R.: Feasibility of carbon-capturing in building heating systems: a life cycle thinking-based approach. Int. J. Greenhouse Gas Control **132** (2023). https://doi.org/10.1016/j.ijggc.2023.104056
5. Moudgil, V., Sadiq, R., Bakhtavar, E., Paudel, A., Hewage, K.: A cloud-oriented data-analysis framework to analyze peak demand dynamics in institutional building clusters. Sustain. Cities Soc. **111**, 105553 (2024). https://doi.org/10.1016/j.scs.2024.105553
6. Liyanage D.R., Hewage K., Ghobadi M., Sadiq R.: Thermal resiliency of single-family housing stock under extreme hot and cold conditions. Energy Build. **323**, 114809 (2024). https://doi.org/10.1016/j.enbuild.2024.114809
7. Wijayasekera S.C., et al.: Sustainability of waste-to-hydrogen conversion pathways: a life cycle thinking-based assessment. Energy Convers. Manage. **270** (2022). https://doi.org/10.1016/j.enconman.2022.116218
8. Jayasena A., Hewage K., Siddiqui O., Sadiq R.: Socio-economic and environmental cost-benefit analysis of passive houses: a life cycle perspective. J. Clean. Prod. **373** (2022). https://doi.org/10.1016/j.jclepro.2022.133718

Short Bio – Prof. Kasun Hewage is a Full Professor and FortisBC Smart Energy Chair in the School of Engineering at the University of British Columbia. He also serves as Associate Director of UBC's Clean Energy Research Centre and Director of the Life Cycle Management Laboratory. Prof. Hewage brings extensive multidisciplinary industrial experience in Canada and internationally. Prior to joining UBC in 2008, he worked as a business management cost specialist in the oil and gas sector and as a civil engineer on hydropower and infrastructure development projects. His research focuses on integrating life-cycle thinking into urban development, energy policy, and infrastructure planning. A distinctive feature of his work is its whole-system perspective, extending beyond conventional assessment methods to evaluate products, processes, and built assets from material extraction through end-of-life. Through this approach, Prof. Hewage and his research team have supported governments, infrastructure developers, and communities in advancing low-impact and net-zero development strategies for both existing and planned communities. Prof. Hewage currently leads many collaborative research projects on life-cycle management of built assets, green construction, smart energy systems, and sustainable community planning. His contributions have helped establish important benchmarks, decision-support methods, and implementation pathways for advancing sustainability in the Canadian and global construction sectors. He has authored or co-authored more than 300 peer-reviewed journal publications, in

addition to numerous book chapters and conference papers presented at national and international forums. Prof. Hewage is registered as a Professional Engineer in British Columbia, Canada. He is a Fellow of the Canadian Society for Civil Engineering, the Canadian Society of Senior Engineers, and the Engineering Institute of Canada.

Machine Learning Based Methodologies for Grape and Wine Production

Pedro Melo-Pinto

University of Trás-os-Montes and Alto Douro, Engineering Department, Centre for the Research and Technology of Agro-Environmental and Biological Sciences, Portugal

Abstract. Wine production is a major area in Portuguese economy. The sector accounts for approximately 2.6% of Portugal's GDP, and is crucial to the development of inland regions. Wine quality depends on grape quality, which is a result of different factors such as harvesting at the optimal point of maturity, or selecting the grapes according to quality features. The growing importance of precision agriculture, demands novel methods to make the most out of the data generated. Machine learning approaches are particularly suitable for complex processes' modelling, where too many arguments are involved. Many of the agricultural processes such as yield estimation or ripening, fall into this category. However, several challenges may arise: even if models are available for particular cases, general models are difficult to come by, largely due to the high variability involved; with such models, there is a need for huge amounts of data, in a way which will not always be easy to obtain. This is particularly true in the case of grape production and the wine industry, where the number of grape varieties, climate, soil, etc., introduce a degree of variability that is uncommon in other sectors. One way of obtaining more information in such cases has been the use of images, whether RGB, multi-spectral or hyperspectral. The use of images introduces additional challenges, such as data size and lighting conditions, which underscores the need for data-driven modelling methodologies. The use of machine learning (ML) techniques combined with images has been establishing itself as a viable alternative predicting yields or quality parameters in grapes, and assist on harvesting critical decisions. Several ML approaches have been proposed to handle such data characteristics, but selecting a suitable methodology that best address the problem under study and make sure it generalizes well, is, most of the times, a cumbersome task. We will address three wine and grape production problems, yield estimation, grape quality assessment and illness detection, presenting different difficulties. Yield estimation is a major aspect in the wine production industry. The number of berries is one of the most relevant yield aspects, and can be estimated using computer vision, namely image segmentation algorithms. Lighting is one of the key factors in computer vision approaches, and occlusions—which are common in this problem—can be minimized, but require estimation models to achieve reliable results. Illness early detection is, of course, of the utmost importance, with an impact on production and quality. Detecting early symptoms and distinguishing them from other conditions is a difficult task, which makes the use of machine learning algorithms advisable, using automatic visual inspection of the leaves, addressed as a pixel-based classification problem. However, the available datasets are limited and complex to compile, as different diseases typically require very

specific timeframes and locations. The use of generative models to overcome this obstacle, in conjunction with robust classification models, lead to models that are intended to be as general as possible. The evaluation of the grape's maturation profile based on the evolution of their oenological parameters over time is one of the most important aspects for ensuring wine quality, playing a decisive role in the definition of the optimal time for harvesting. The use hyperspectral imaging combined with learning algorithms represents a faster and non-destructive grape ripeness assessment method. We focus in two fundamental aspects to address the resulting data variability: a possible wavelength bands selection (with the purpose of reducing the dimensionality of data without losing predictive power) and the generalization ability of the ML model under such demanding conditions.

Short Bio – Pedro Melo-Pinto graduated from Univ. do Porto in 1984 and received a Ph.D. in Computer Science from the Univ. de Trás-os-Montes e Alto Douro (UTAD) in 1998. He is a Full Professor at UTAD where he served as Pro-Rector, as Director and Vice-Director of R&D units, and as member of UTAD's General Council. He also served as a member of The Portuguese Strategic Infrastructures (for the Digital Areas) Monitoring Committee and usually serves as a member (or co-chair) of the evaluation panel for different Portuguese and international R&D projects and grants competitions. He is currently Associate Editor of Computers and Electronics in Agriculture journal. He was Chair of the EuroFuse 2011 conference and the NATO 2001 Advanced Research Workshop, and served as member of the organization committee for more than 40 international conferences/workshops/special sessions. He is the head of the Image-Based Systems Lab from the Centre for the Research and Technology of Agro-Environmental and Biological Sciences.

His scientific interests include Computer Vision (CV) and Machine Learning (ML) and, in the last 15 years, their applications to the Agro-forestry area, namely to grape oenological parameters assessment. He authored/co-authored more than 100 scientific papers. He participated in many Portuguese and international R&D projects, predominantly in the areas mentioned above.

Contents

Computational Methods, Algorithms and Scientific Applications

Securing Corporate Data Exchange: An Efficient Identity-Based Authenticated Signcryption Over Elliptic Curves 3
Minh Tu Le, Van Nghi Nguyen, Hanh Thi Tran, Minh Thang Vu, and Van Duan Nguyen

Algorithmic Complexity Underpins When Path Information Improves Graph Neural Networks Performance on Molecular Graphs 18
Abdulrahman Ibraheem, Narsis Kiani, and Jesper Tegner

A Systematic Performance Study of Parallel Programming Models for Stencil-Based CFD Applications on Heterogeneous Architectures 35
Mariana Padilha, Claudio Schepke, Tailí Petry, and José Rufino

Uncertainty Quantification of Underwater Sound Propagation Using Surrogate Models 51
Mikhail S. Lytaev

Low-Cost Wearable System for Essential Tremor Monitoring with Passive Damping 67
Gustavo Adolpho Bonesso, Carlos Marcelo Gurjão de Godoy, Eliana Chaves Ferretti, and Regina Célia Coelho

Analyzing Internal Sensitivity in Neural Network Representations via Jacobian Norms and Perturbation Analysis 79
Aninda Kumar Sharma

Numerical Algorithm for the Biermann Effect in ICF Self-generated Magnetic Fields and Its Applications 96
Yang Rong, Song Peng, and Wang Qiang

Frequency Domain Prediction of NACA 0012 Self-noise Using Data-Driven Machine Learning 110
Rishav Mishra, Alvis Fong, and Bade Shrestha

Beyond Endpoint Quality: A Phase-Aware Analysis of Search Dynamics in Triangle Reassembly 130
Damir Hasanspahić, Adis Alihodžić, and Damir Hasić

Mesh Optimization for the One-Way Helmholtz Equation in an Inhomogeneous Medium 144
Mikhail S. Lytaev

New Metaheuristic Algorithms to Reduce the Bandwidth of Real-World Graphs 161
Alexandre Augusto Alberto Moreira de Abreu and Sanderson L. Gonzaga de Oliveira

Shelf Space Allocation with Rectangular Arrangement: A Comparative Study of Three MILP Formulations 179
Daniel Martins, Maria João Alves, and Cristela Bairrada

Architecture Foundations and Deployment Scalability for CWMP: A Technical Review 192
Marco Marinello

Less is More: XAI-Driven Feature Selection for Efficient Molecular Property Prediction 204
Jonas Lucas Durão, Luís G. Dias, and Marcos G. Quiles

High Performance Computing and Networks

AMMOF: An Adaptive Multi-metric Objective Function for Enhanced RPL Routing in Industrial IoT Networks 221
Lyes Ibersiene, Badis Djamaa, Mustapha Reda Senouci, Ahmed Yadine Merabet, and Oussama Zahali

Design and Experimental Evaluation of Secure Overlay Networks for Docker Microservices Architectures 236
Damiano Perri, Osvaldo Gervasi, and Francesco Bietolini

Dynamic Regression Algorithm and Multi-Objective Query Optimization in Spark SQL 251
Trung-Dung Le

Analyzing Optimization Trade-Off Between Energy and Model Convergence in Federated Learning 269
Nilo Marchiori Louzada, Renato Elias Nunes de Moraes, Rodolfo S. Villaça, Vinícius F. S. Mota, and Maria Claudia Silva Boeres

2D CNN-Based Link Prediction in Opportunistic Networks 287
Vinícius da Silva Thiago, Ronaldo Moreira Salles, Julio Cesar Duarte, and Gabriela Moutinho de Souza Dias

Evaluating Accuracy–Performance Trade-Offs in Deep Learning Frameworks for Diabetic Retinopathy Detection 303
Bruno Morales, Cristiano Künas, Rodrigo Machado, Pedro Rigon, and Philippe O. A. Navaux

Topology-Aware Distributed Ensemble Learning Using the vCube Hierarchical Hypercube Overlay 321
Charles Giovane Salles, André Luiz Brun, and Luiz Antonio Rodrigues

Automating the Technical Validation of FHIR Implementation Guides: A Data-Oriented Framework Within the HfPT Project 340
Ivo A. Rodrigues, Leopoldo O. Silva, Cátia Pereira, Rute Almeida, Rui C. Ribeiro, and Francisco J. Duarte

Characterizing Lossless GPU Data Compression Across AMD CDNA and RDNA Architectures 357
Cristiano Künas, Gabriel Freytag, Jean Luca Bez, Thiago Araújo, and Philippe Navaux

A Systematic Literature Review of Network-on-Chip Architectures: Topologies, Routing, Reliability, and Emerging Technologies 375
Asrani Lit, Rohana Sapawi, Shamsiah Suhaili, Sharifah Masniah Wan Masra, and Kuryati Kipli

Geometric Modeling, Graphics and Visualization

Adaptive Hyperspectral Image Classification Using a CNN-MAOELM Hybrid Architecture 393
Oleksii Fesenko, Robert Bieliakov, Hryhorii Radzivilov, Andrii Bernatskyi, and Dmytro Koltovskov

A Re-parameterized Multi-scale and Global Context Framework for Waste Detection in Vietnamese Street Scenes 413
Phat Hoang Ho, An Hoang Nguyen, Kien Trang, and Bao Quoc Vuong

LCRO-GAN: A Multi-stage GAN Framework for Image-Based Reconstruction of Historical Monuments 428
Pranav Jigalur, Likhith Gowda, Kripa S Rai, Praveen Koppal, and Sindhu R Pai

Run-Time Assurance for Onboard COTS-Based AI in Safety-Critical LEO Small-Satellite Systems 445
Omer Khalid, Jose-Carlos Gamazo-Real, and Elena Roibás-Millán

Surgical Instrument Tracking: a Lightweight YOLO Approach Across Diverse Domains 461
Nathalia Frederico, Rafael Miranda, Saulo Silva, and Jefferson Morais

Deep Learning-Based Crack Detection on Complex Decorative Surfaces of Cultural Heritage Artifacts 478
HongYi Shih, Debora Verniz, Filiz Bunyak, and Jessica Boldt

StableZero: Improving General Image Generation Through Visualisation Feedback 492
Kazim Laos, Hector D. Menendez, and Gema Bello-Orgaz

From Random to Pre-trained ViT Backbones for Improved Feature Extraction: Application to Diagnosis with Sensor Images 510
Luan B. Guerra, Ana Beatriz S. Zerati, Wallace Casaca, and Lucas C. Ribas

Classification of Dynamic Libras Signs Related to the Hospital Context Using Recurrent Neural Networks 529
Pedro de Araújo Bhering Bittencourt, Luiz Maurílio da Silva Maciel, Marcelo Bernardes Vieira, and Saulo Moraes Villela

A Comparative Study of Prompt Engineering Strategies for Data Visualization Scenarios 544
Camile Maria Cunha Aguiar, Walbert Cunha Monteiro, Thiago Augusto Soares de Sousa, Roberto Yuri da Silva Franco, and Bianchi Serique Meiguins

Detection of Cow Face and Subregions Using a New Annotated Dataset 561
Mathews Edwirds Gomes Almeida, Pedro de Araújo Bhering Bittencourt, Brian Luís Coimbra Maia, Lucas Silva Santana, João Vítor de Castro Martins Ferreira Nogueira, Daniel Muller Rezende, Gabriel Rezende da Silva, Thais de Souza Marins, Luiz Maurílio da Silva Maciel, Marcelo Bernardes Vieira, Saulo Moraes Villela, and Bruno Campos de Carvalho

Enhanced Architecture for Non-destructive Leaf Area Estimation Based on a Semantic Segmentation Network 580
Caio Seixas Duarte, Luiz Maurilio da Silva Maciel, Saulo Moraes Villela, and Marcelo Bernardes Vieira

Advanced and Emerging Applications

Beam Forming and Super-Grouping for Seismic Data Enhancement in 5D Domain 599
Maxim Protasov, Maxim Dmitriev, Young Seo Kim, and Denis Sabitov

Quantile Regression for Soil Organic Carbon: A Distributional Analysis of Soil Variability 613
Edson L. Almeida, Ian Alexander Zahner McIntosh, Joel André Ferreira dos Santos, Ana Carolina Ferreira, Angela Ferreira, Jorge Soares, Marcos Bacis Ceddia, and Diego Brandão

Comparative Evaluation of Filter and Wrapper Feature Selection Methods in Species Distribution Modeling 628
Yousra Cherif and Ali Idri

Provision of Financial Security of the State and Ways of Threat Prevention 644
Nadiia Davydenko, George Abuselidze, Olena Gudz, and Svitlana Onyshko

Bayesian Models to Predict Above Ground-Biomass 660
Ricardo Coelho, Isabel Natário, and Silvia Fraile

Author Index 679