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Computational Science and Its Applications – ICCSA 2026 Workshops

Braga, Portugal, June 30 – July 3, 2026
Proceedings, Part IX

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Preface

These 9 volumes (LNCS volumes 16758–16766) comprise the peer-reviewed papers from the 57 Workshops 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 six main conference tracks are published in a separate set of 3 volumes (LNCS volumes 16767–16769).

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 Conference 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), 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,

and their applications across the most diverse technological, economic, and industrial fields, amongst others.

The ICCSA 2026 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 a few. In addition, ICCSA 2026 included 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.

For these Workshops Proceedings, we accepted 328 full papers, 23 short papers, and 3 Ph.D. Showcase papers from a total of 1184 submissions (acceptance rate 29.9%). Reviews were single blind, and submissions received 2.6 reviews each, on average. In the Main Conference Proceedings, we accepted 119 full papers, 3 short papers, and 2 Ph.D. Showcase papers from 431 submissions to the General Tracks of the Conference (acceptance rate of 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, 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 Guimaraes 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 particiapnts could 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.

We enjoyed meeting you in Braga.

Sincerely yours,

On behalf of the Local Organizing Committee.

June 2026 Ana Maria A. C. Rocha

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Computational Astrochemistry 2026 (CompAstro 2026)

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Computational methods for Porous materials (CompPor 2026)

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Evgeniy Romenski	Sobolev Institute of Mathematics, Russia

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Sergey Solovyev	Sobolev Institute of Mathematics SB RAS, Russia
Vladimir Cheverda	Sobolev Institute of Mathematics SB RAS, Russia

Workshop on Computational Science and HPC (CSHPC 2026)

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Robert Makin	Western Michigan University, USA

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Fukuko Yuasa	KEK, Japan
Shigeyoshi Aoyama	KEK, Japan
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Cities, Technologies and Planning (CTP 2026)

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Anastasia Stratigea	National Technical University of Athens, Greece
Ljiljana Zivkovic	Republic Geodetic Authority, Serbia
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Francesca Sinatra	University of Trieste, Italy

Evaluating Inner Areas Potentials (EIAP 2026)

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sustainablE mobiLity and Last mIle lOgisTic in urban context (ELLIOT 2026)

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Econometrics and Multidimensional Evaluation in Urban Environment (EMEUE 2026)

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Giuseppe Ciciriello	University of Naples Federico II, Italy
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Ecosystem Services in Spacial Planning for climate neutral urban and rural areas (ESSP 2026)

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Federica Leone	University of Cagliari, Italy
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The 16th International Workshop on Future Information System Technologies and Applications (FiSTA 2026)

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Toshihiro Yamauchi	Okayama University, Japan
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Geographical Analysis, Urban Modeling, Spatial Statistics (Geog-And-Mod 2026)

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

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Geomatics for Resource Monitoring and Management (GRMM 2026)

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

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Teresa Guarda	Universidad Estatal Península de Santa Elena, Ecuador

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

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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
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Multidimensional Evolutionary Evaluations for Transformative Approaches (MEETA 2026)

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Maria Cerreta	University of Naples Federico II, Italy
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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

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Simona Panaro	University of Sussex Business School, UK
Eugenio Muccio	University of Naples Federico II, Italy

Building multi-dimensional Models for assessing complex Environmental Systems (MES 2026)

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Vanessa Assumma	University of Bologna, Italy
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Federico DellAnna	Politecnico di Torino, Italy
Marta Dell'Ovo	Politecnico di Milano, Italy
Marco Rossitti	Politecnico di Milano, Italy

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Chiara D'Alpaos	University of Padua, Italy
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Giorgia Sugoni	Links Foundation, Italy
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Computational Mechanics, Intelligence, and Data (MIND 2026)

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Renato Zona	Università della Campania Vanvitelli, Italy

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Donato Perfetto	University of Campania Luigi Vanvitelli, Italy

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

Workshop Organizers

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Valerio Cutini	University of Pisa, Italy

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Chiara Garau	University of Cagliari, Italy
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Chiara Di Dato	University of L Aquila, Italy
Giampiero Lombardini	University of Genoa, Italy

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Federica Deri	University of Pisa, Italy
Chiara Anselmi	University of Pisa, Italy

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

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Valentina Giorgetti	Università degli Studi di Perugia, Italy
Vita Leonessa	University of Basilicata, Italy

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) CNR, Italy

Francesco Zullo	University of L'Aquila, Italy
Alessandro Marucci	University of L'Aquila, Italy

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Giuseppe Borruso	University of Trieste, Italy
Chiara Garau	University of Cagliari, Italy
Beniamino Murgante	University of Basilicata, Italy
Ljiljana Zivkovic	Republic Geodetic Authority, Serbia
Luigi Santopietro	Institute of Methodologies for Environmental Analysis National Research Council of Italy CNR IMAA, Italy
Ilaria Delponte	University of Genoa, Italy
Carmen Guida	Università degli Studi di Napoli Federico II, Italy
Chiara Di Dato	University of L'Aquila, Italy

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

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

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Giuseppe Fiorillo	Parthenope University of Naples, Italy
Marco Lettiero	University of Naples Parthenope, Italy
Francesco Peluso	University of Naples Parthenope, Italy

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

Workshop Organizers

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

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Bruno Veloso	Universidade do Porto, Portugal
Luís Louro	University of Minho, Portugal
Weronika Wojtak	CCG/ZGDV Institute, Portugal
Wolfram Erlhagen	University of Minho, 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

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Gianni D'Angelo	University of Salerno, Italy
Biagio Boi	University of Salerno, Italy
Luigi Piero Di Bonito	Università degli Studi della Campania, 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

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Marilisa Biscione	Institute of Heritage Science of the National Research Council of Italy (CNR ISPC), Italy
Valentina Florio	CNR, Italy
Antonio Minervino Amodio	Institute of Heritage Science of the National Research Council of Italy (CNR ISPC), Italy

Scientific Computing Infrastructure (SCI 2026)

Workshop Organizers

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Elena Stankova	Saint Petersburg State University, Russia

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Suren Abrahamyan	Institute for Informatics and Automation Problems of NAS RA, Armenia
Ashot Gevorkyan	Institute for Informatics and Automation Problems NAS of Armenia, Armenia

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Alexander Degtyarev	Saint Petersburg State University, Russia
Alexander Bogdanov	St. Petersburg State University, Russia
Nataliia Kulabukhova	AutoTech, Russia
Alexander Degtyarev	St.Petersburg State University, Russia
Alexander Bogdanov	St. Petersburg State University, Russia

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

Workshop Organizers

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

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Antonella Roma	Sapienza University of Rome, Italy
Francesca Fariello	Sapienza University of Rome, Italy

Ports and logistics of the future - Smartness and Sustainability (SmartPorts 2026)

Workshop Organizers

Andrea Gallo	Università degli Studi di Trieste, Italy
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Plenary Lectures

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

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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 critically reflects on the tensions between technological ambition and civic inclusion, exploring themes such as transparency, interoperability, participation, and trust. It also discusses 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.

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

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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. Closing 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.

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

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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 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.

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Machine Learning Based Methodologies for Grape and Wine Production

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Abstract. Wine production is a major area in the 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 modelling complex processes, 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 for predicting yields or quality parameters in grapes, and assisting with critical harvesting decisions. Several ML approaches have been proposed to handle such data characteristics, but selecting a suitable methodology that best addresses the problem under study and making sure it generalizes well is, most of the time, 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. Early illness 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 time-frames and locations. The use of generative models to overcome this obstacle, in conjunction with robust classification models, leads 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 of 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.

Contents

Virtual Reality, Augmented Reality and Applications (VRA 2026)

Indoor Pilot 3D Representation of Comfort Conditions in Mixed Reality Environment 3
Stelios Kouzeleas, Ioannis Tsolakidis, and Eleni Vlachonasiou

Smart City Digital Twin Framework for Semantic Indexing and Dynamic Modelling of 3D Buildings 21
Marco Fanfani, Federico Galli, Chiara Garau, Paolo Nesi, and Gianni Pantaleo

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

Integrating GIS-Based Spatial Analysis and Structural Modeling for the Adaptive Reuse of the Santa Chiara Dam 37
Enrica Vecchi and Marco Zucca

Integrated Geophysical Study at the Colonel Henry Anderson Morshead Burial Memorial, Valletta: Preliminary Results 54
Sebastiano D'Amico, Luca Piroddi, Emanuele Colica, Luciano Galone, and Mario Farrugia

Investigating the Castello Archaeological Park (Cersosimo, Italy) Using a Combination of Geophysical Prospections, Aerial and Terrestrial Photogrammetry 68
Marilena Cozzolino, Vincenzo Gentile, and Paolo Mauriello

Assessment of Low-Cost GNSS Receiver Performance in Urban Environments 86
Giuseppina Vacca, Enrica Vecchi, and Antonio Pala

Integration of 3D Ultrasonic Tomography, Photogrammetry, and Mixed Reality for the Structural Assessment of the Marble Statue "Caino" 104
Marco Vincenzo Majani, Alessandra Carollo, Raffaele Martorana, and Patrizia Capizzi

PHD Showcase Papers

An Efficient and Stable Solver for the Shallow Water Equations on Regular Latitude-Longitude Grids Using Spherical Fourier Transforms 117
Suzune Nomura and Takeshi Enomoto

Explainable and Accurate Valvular Heart Disease Screening Using Spectrogram-Based 2D-CNNs on PCG Signals 135
Talha Ahmed Siddiqui, Sania Akhtar, Muhammad Taha Mansoor, Badee Baltow, Sadaq-Ur Rehman, and Noor Ul Huda

Revisiting Ray-Tracing Algorithm for Future Limb-Scanning Missions 153
Francesco Pio De Cosmo and Luca Sgheri

Short Papers

Artificial Intelligence for Photovoltaic Power Forecasting in Energy Management 173
Guillermo Blanco, Marco Melgarejo, Alejandro Pérez, and Camilo Palazuelos

Economic Assessment of Inclusive Tourism in a Silk Road Heritage Destination: A Monte Carlo Simulation Study of Samarkand, Uzbekistan 186
Bahodirhon Safarov, Habibullo Hasanov, Makhina Buzrukova, and Elena Salnikova

On Battery Storage Management by Sparse Linear Programming 197
Ana Maria A. C. Rocha, Pablo Guerrero-García, and Eligius M. T. Hendrix

On Subproblem Solving in an Augmented Lagrangian Algorithm for LP with Upper Bounds 206
Eligius M. T. Hendrix, Pablo Guerrero-García, and Ana Maria A. C. Rocha

Resilient Mobility Under Multiple Shocks: The SCUDO Project Experience . . . 217
Francesco Bruzzone, Matilde Gasparetto, and Silvio Nocera

ViBERT-ESG: Advancing ESG Classification in Vietnamese with ViEnESG-100 Dataset 226
Vanmanh Nguyen, Ductrung Tran, Kienlam Do, Thiloan Bui, and Vanha Tran

Machine Learning Assisted Two-Level Mixed Finite Element Method for the Darcy–Forchheimer Model 236
Johnson Daddy Audu and Faisal Fairag

On the Travelling Wave Solutions of a Non-linear Reaction-Diffusion-Advection Model for Forest Fire Spread 247
Donato Pera, Cordula Reisch, Federica Di Michele, and Bruno Rubino

Anomaly Detection and Root Cause Analysis of Retainability Contextual Anomalies in Radio Access Networks 259
David Santos, Paula Amaral, João Martins, and Rui Ramos

THEMATIC2GREEN: Strengthening Innovation Capacity for a Place-Based Green Transition in Fragile ADRION Territories 270
Michele Greco, Francesco Scorza, Biagio Perretti, Francesco Paolo Del Giudice, Alfonso Annunziata, and Beniamino Murgante

A Unified Energy Decomposition and Delocalization Approach to Rare-Gas Excimer Bonding 281
Marcos Mandado

Molecular Dynamics Simulations of Nanoemulsions: Effect of the Initial Geometry and Concentration 291
Jose Manuel Hermida-Ramon and Sonia Losada-Barreiro

Transport Disruption Vulnerability in Europe: Who Is Worse Off? 300
Francesco Bruzzone, Hamza Begic, Silvio Nocera, and Constantinos Antoniou

Backlog Traps, Congestion and Sustainable Transition in Port Systems: A System Dynamics Approach 311
Ani Simonyan and Giuseppe Borruso

On the Behavior of PATE Under Class Imbalance and Non-IID Data 327
Alexander Bogdanov, Valery Khvatov, Yueh Chiang, and Nadezhda Shchegoleva

Traffic Flow Analysis of Closely Spaced Roundabouts and Signalized Intersections 338
Mirna Klobučar, Aleksandra Deluka-Tibljaš, Sanja Šurdonja, and Irena Ištoka Otković

Evaluating the Impact of Traffic Control System Failures on Intersection Level of Service Using Microsimulation 351
Denis Codroiu, Eugen Rosca, Aura Rusca, Maja Skuric, Oana Dinu, Valentina Radu, and Armand Stere

Control Point Detection for Network Alignment Using Large Language Model 365
Müslüm Hacar and Özge Öztürk Hacar

Active Reflectors and Passive Corner Reflectors for Deformation Monitoring Using DInSAR Interferometry: Some Remarks from Sentinel-1 Imagery Tests 374
G. Luzi, P. Espín-López, and Q. Gao

Statistical Anomaly Detection Using LC-Curves: An Application to Geophysical Time Series 384
Fuad Aleskerov and Aleksei Kosychev

A Robotic GPR Pipeline for Automated Subsurface Analysis in Multiple Scenarios 393
Nuria Rodríguez Calderón, Berta Viñes Santamaria, David Caballero Flores, Tahzeeb Hussain, and Vega Perez-Gracia

Decarbonising Long-Distance Transport: Modal Shift from Short-Haul Aviation to High-Speed Rail for Sustainable Mobility 405
Oana Dinu, Eugen Rosca, Ilona Costea, Andrea Alonso Ramos, Aura Rusca, Anamaria Ilie, and Cristian Marin

Nanofluid Injection in Poroelastic Media: Possible Applications in Environmental Science 416
Rosella Sampalmieri, Federica Di Michele, Donato Pera, and Bruno Rubino

Author Index 427