

ISPRS Technical Commission IV Midterm Symposium 2024: Preface

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Commission IV is dedicated to advancing spatial modeling and enhancing the interoperability of geospatial data fusion, with a strong emphasis on exploring open data and software. The Commission's intensive research activities cover areas such as spatial analysis, data quality, uncertainty modeling, and artificial intelligence, leading to the development of cutting-edge tools. Its members are committed to high-performance geo-computation, the integration of crowdsourced data, the Internet of Things (IoT), and community-driven intelligent systems. The focus on indoor/outdoor services, spatial data management, visual analytics, and virtual/augmented reality aligns with the overarching goal of Technical Commission IV (TC IV) to create human-centered applications. The Commission's work significantly contributes to urban modelling, sustainable decision-making, and the application of spatial information across various fields, all in alignment with the United Nations Sustainable Development Goals (UN SDGs) for global impact.

In today's rapidly evolving world, digital twin models of reality are increasingly essential for governments and businesses to address environmental and socio-economic challenges while promoting sustainable development. The growing need for effective decision-making in dynamic environments underscores the importance of complex, multi-dimensional geospatial data. Digital twins and the metaverse have emerged as pivotal technologies, enabling the testing and analysis of intricate systems and overcoming challenges such as data discovery, visualization, sharing, fusion, analysis, and simulation, alongside managing large-scale multidimensional data with geoAI models.

As the world changes, digital representations of reality are becoming critical tools for governments and businesses to understand and manage environmental and socio-economic issues, drive sustainable development, and reduce emissions. The increasing pressure on living and working spaces further necessitates decisions based on complex, multi-dimensional spatial data. Digital twins have become a crucial technology, providing a platform for testing and analyzing complex systems that would be impossible to evaluate with traditional simulators and modular assessments. However, the development of such technology faces significant challenges, including the discovery, sharing, fusion, analysis, and simulation of spatial information, the availability of data to train machine learning models, and the management and visualization of large multidimensional datasets. The ISPRS TC IV 'Spatial Information Sciences' is dedicated to advancing spatial information science, enabling the development of spatial digital twins, and empowering their evolution into the metaverse. The Commission addresses several key challenges, including multidimensional modeling, data fusion, open data, big data management, spatial analysis and simulation, mixed reality, and advanced interfaces. With a four-year mandate (2022-2026), the Commission's research and development activities are carried out by 11 Working Groups and two Inter-Commission Working Groups, coordinated by 55 ISPRS officers and over 100 members. The ISPRS Technical Commission IV Symposium serves as a platform for researchers and practitioners to share their work and ideas, discuss opportunities and challenges, exchange developments or software tools, and explore future directions. The symposium also provides an excellent opportunity for networking and fostering connections between academia, governments, businesses, and young and emerging professionals in the geospatial sciences.

The Commission's activities are organized into 11 Working Groups (WG) and two Inter-Commission Working Groups. WG 1 (Spatial Data Representation and Interoperability) focuses on spatial data representation and interoperability, emphasizing international standards, best practices for data management, and collaboration with standardization organizations. WG 2 (Artificial Intelligence and Uncertainty Modeling in Spatial Analysis) explores artificial intelligence and uncertainty modeling in spatial analysis, covering data mining, machine learning, spatial statistics, and uncertainty visualization. WG 3 (Geo-computation and Geo-simulation) is centered on geo-computation and geo-simulation, investigating high-performance techniques, knowledge-based methods, and their effective integration into spatial decision support systems. WG 4 (Data Management for Spatial Scenarios) addresses data management for spatial scenarios, focusing on interfaces, standards, and strategies for managing large and heterogeneous geospatial datasets. WG 5 (Extended Reality and Visual Analytics) explores human factors, geo-visualization evaluations, and innovative tools for exploring complex phenomena. WG 6 (Human Behavior and Spatial Interactions) delves into understanding human behavior and spatial interactions, addressing models, uncertainties, spatial analysis technologies, and strategies for handling geo-privacy and ethical concerns. WG 7 (Intelligent Systems in Sensor Web and IoT) focuses on intelligent systems in the sensor web and IoT, covering sensor data fusion and new analysis methods. WG 8 (Digital Twins for Mobility and Navigation) concentrates on digital twins for mobility and navigation, with an emphasis on conceptual frameworks, algorithms, standards, and solutions for sustainable and resilient mobility. WG 9 (Spatially Enabled Urban and Regional Digital Twins) focuses on AI-based methods and BIM/GIS integration. WG 10 (Applied Spatial Science for Public Health) covers spatial technologies, citizen science, AI for hotspot detection, and multidimensional data handling for health. WG 11 (Cultural Heritage Visualization and Virtual Restoration) addresses cognition, data integration, deterioration monitoring, deep learning, digital storytelling, and sustainable development. ICWG IV/III (Global Mapping for SDGs) tackles challenges in geospatial information use and innovative methods for

monitoring SDGs. Finally, ICWG IV/III/II (Openness in Geospatial Science and Remote Sensing) focuses on openness in ISPRS-related fields, promoting reproducibility, best practices, and stakeholder communication.

The Commission aims to enhance the visibility of spatial information research through initiatives such as facilitating data exchange and open software, recognizing achievements, and fostering collaboration among its Working Groups and with other international scientific organizations.

The symposium was held in Fremantle, Perth, Australia 22 – 25 October, 2024, together with UPINLBS 2024, Geospatial Council of Australia (GCA), and hosting FOSS4G Perth.

UPINLBS is an international conference series supported by ISPRS, focusing on ubiquitous positioning, indoor navigation, and location-based services. Indoor positioning remains a critical yet challenging research area due to the complex spatial geometry and signal propagation indoors, with low-cost high-precision solutions still lacking. Emerging research includes Beidou + 5G positioning, brain-inspired navigation, and robot localization. The Geospatial Council of Australia, the peak body for geospatial professionals, hosts ISPRS TCIV (2022-2026). FOSS4G Perth is a local event celebrating open-source geospatial tools, fostering community engagement, and connecting with the global ISPRS network.

These joint events have fostered collaboration among research communities, reflecting the TC's mission to unite academics and industry professionals in Spatial Information Sciences (SIS) to share the latest research and technological advancements. The Commission's plan also prioritizes expanding ISPRS TC IV's influence within diverse SIS research communities and promoting the exchange of knowledge generated by its working and inter-working groups.

Six speakers provided inspiring talks to enrich and share their experiences with the attendees. Barbara Ryan, presenting "From Digital Twins to the Metaverse", discussed the evolution of digital twins from manufacturing to broader applications, such as cities and entire regions. She highlighted how these digital representations could be integrated globally, ultimately leading to a comprehensive "Metaverse" that models the Earth system. Ryan's extensive career includes leadership roles in the USGS (United States Geological Survey), WMO (World Meteorological Organization) and GEO (Group on Earth Observations), contributing significantly to the accessibility of Earth observation data. Karen Joyce, a geospatial scientist with experience in academia, the military, and industry, talked about "A Biographer for Mother Earth". She uses satellites and drones to monitor environmental changes, aiming to inspire more people to engage in environmental conservation. Qihao Weng with the talk "How AI Will Transform Urban Observing, Sensing, Imaging, and Mapping", explored how AI and Earth observation data are revolutionizing urban studies. He emphasized AI's potential to enhance urban sensing, imaging, and mapping, enabling more detailed and human-centered analysis. Weng also discussed challenges in integrating diverse geospatial big data and ensuring data security. Renee Bartolo delivered a compelling presentation titled "Curious Creatures, Ghost Nets, Weeds, and Environmental Monitoring," where she detailed her innovative use of drones and AI for environmental monitoring across remote regions of Australia. Highlighting the importance of collaboration, she shared how her team partners with First Nations rangers to implement culturally appropriate technology, emphasizing the critical role of real-time data streaming in conservation efforts. Bartolo's operations extend from Antarctica to Christmas Island, focusing on preserving biodiversity and addressing environmental challenges. In his talk titled "UN Smart Maps - An Open Initiative for Data Fusion," Hidenori Fujimura introduced the UN Smart Maps initiative, which aims to revolutionize geospatial data operations through the use of cutting-edge technologies such as the Interplanetary File System (IPFS) and Large Language Models (LLMs). Fujimura underscored the importance of open and participatory approaches to enhance global geospatial data sharing and interoperability, aiming to make geospatial resources more accessible and integrated for a better world. Ahi Saipaia presented "From Paddock to Polygon," where she discussed the collaborative development of the open-source geospatial system, Maplandscape, in Tonga. This system has transformed how agricultural landscapes are mapped and monitored, significantly advancing the Kingdom's agricultural data collection and decision-making capabilities. Saipaia was instrumental in modernizing the Ministry of Agriculture, Food, Forests and Fisheries (MAFFF)'s processes, enhancing their geospatial expertise, and ensuring the sustainability of these tools in Tonga's agricultural sector.

Seven workshops were organized, each focusing on a diverse range of topics designed to enhance knowledge and skills in geospatial science and related fields.

TU1 (Approaches for Simplifying 3D Data Exchange Between Systems) introduced techniques for simplifying 3D data exchange between different systems. Rob Atkinson from the OGC led this session, offering insights into profiling, semantic uplift, and reusable schema building blocks, using case studies like the CHEK project to demonstrate these approaches.

TU2 (Uncovering Earth System Dynamics with Multivariate EO Data and AI) delved into Earth System dynamics using multivariate Earth Observation (EO) data and AI. Martin Reinhardt of the University of Leipzig and Anca Angheloa from the European Space Agency introduced participants to the DeepESDL platform, providing hands-on training in creating AI-ready datasets, data cubes, and applying AI techniques to explore global dynamics.

TU3 (Advancing Air Quality Research and Public Awareness Through Innovative Geospatial Technologies) focused on advancing air quality research through innovative geospatial technologies. Maria Antonia Brovelli of Politecnico di Milano and Eva S. Malinverni from Università Politecnica delle Marche demonstrated how to create open data cubes and XR solutions for virtual visualization, integrating EO and IoT data to raise public awareness and promote healthier communities.

TU4 (Creating Immersive GIS Experiences with XR Technology and Real World Data), led by Morakot Pilouk from Esri, explored the creation of immersive GIS experiences using XR technology. Participants learned how to build AR and VR applications by leveraging game engines and the ArcGIS Maps SDK, enabling real-time interaction with geospatial data.

TU5 (Collecting Data in the Field with Free & Open Source Geospatial Tools: QGIS, QField, and Merjin Maps) led by Martin Reinhard, introduced free and open-source tools for field data collection, including QGIS, QField, and Merjin Maps. Grant Boxer, John Duncan, and John Bryant guided participants through project setup, a field data collection exercise, and syncing data to a cloud platform.

TU6 (AI for Geospatial Science), chaired by Zhilin Li from Southwest Jiaotong University, discussed the transformative impact of AI on geospatial science. The tutorial covered topics like AI-empowered spatial data handling, cognition, and how emerging technologies like GPT-4 are shaping the field. The workshop was closed with a panel discussion with Panel discussion on AI for Geospatial Science. The panelist were Li Zhilin, Jun Chen, Tinghua Ai, Nicholas Hamm, Cheolhee Yoo, Yongze Song.

Finally, TU7 (3D Spatial Modeling and Intelligence for Scene-Realistic Analysis and Digital Twin) addressed 3D spatial modeling and intelligence for digital twin applications. Bisheng Yang of Wuhan University, alongside experts like Chen Yiping, Stephan Winter, Lin Hui, Weilian Li, Kourosh Khoshelham, and Zhu Jun, led presentations and a panel discussion on cutting-edge techniques and challenges in this rapidly evolving area.

The symposium offered five technical tours organised by the Western Australia Department of Transport, West Australia Shipwrecks Museum, Fremantle and Curtin University as follows:

TT1 (Marine Operations Centre (MOC) at the Department of Transport (DoT) highlighted the range of equipment necessary to provide valuable hydrographic and oceanographic data to Western Australian organisations.

TT2 (Newman House – Home of the Department of Transport (DoT)'s Maritime division) presented the new DoT Maritime offices and provided an insight into the operations of the coastal information branches' various functions. It also provided an insight into how GIS plays a critical part in the management of marine emergency and environmental response operations.

TT3 (D Shed – Home of the Department of Transport (DoT)'s State Response Equipment and National Plan Equipment Stockpile) offered and walking experience through DoT State Response Equipment Stockpiles that are collocated with AMSA National Plan Equipment Stockpile, in D Shed Fremantle Port. The participants got familiar with oil spill response equipment and consumables that are housed in Fremantle Port for the metropolitan and wider (if required) state response efforts. AMSA-specific vessels, dispersants, and equipment along with DoT first strike capabilities were both be on hand for participants to view.

TT4 (WA Shipwrecks Museum, Fremantle) presented the history of the timber hull of the wrecked VOC ship Batavia (1629), excavated over four seasons in the 1970s, now conserved and on permanent display in the WA Shipwrecks Museum's Batavia Gallery.

TT5: Shipwreck Visualisation at the Curtin University HIVE. The Curtin Hub for Immersive Visualisation and eResearch (HIVE) team has 3D modelled a wide range of shipwreck sites around Australia and overseas, including HMAS AE1 submarine (1914), German battleship Bismarck (1941), HMAS Sydney (II) (1942), HSK Kormoran (1942), SS Bonnie Dundee (1877), B17 "Black Jack" aircraft (1943), Kyrenia wreck (300BC), and many more. These were presented during the visit at HIVE.

During the symposium four panels took place on featuring The role of international organisations (ISPRS) in the world of AI and Digital Twins, UN-GGIM: empowering community with ethical use of GeoAI, Academia-Industry Collaboration for Geospatial Technology and Science Education, and Industry Use Cases of Digital Twin.

The symposium offered presenters and attendees an engaging platform to share research findings, disseminate advancements in new and emerging theories, and showcase applications and technologies within the spatial information sciences. The research presented at the event was documented through papers and abstracts published in the traditional proceedings of the 2024 ISPRS TC IV Midterm Symposium, which includes the ISPRS Annals and ISPRS Archives. These papers were selected through a rigorous peer-review process. The ISPRS Annals feature 67 papers, while the ISPRS Archives include 107 papers. The symposium accepted 98 'abstract-only' submissions, of which 47 were presented in short oral presentations. The program comprised 173 oral presentations, of which 17 were given by industry and governments.

We are grateful to the journals ISPRS Journal of Geoinformation, International Journal of Applied Earth Observation and Geoinformation, Geomatica, Geo-Spatial Information Science, Journal of Spatial Science and the Smart Cities, which provided support to organize spatial issues on topics discussed during the symposium.

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