Symposium J02: Artificial Intelligence and Machine Learning in Geodesy

Conveners: Benedikt Soja, Maria Kaselimi

Recent advancements in artificial intelligence (AI) and machine learning (ML) are revolutionizing numerous scientific fields, and geodesy is no exception. This symposium explores the profound impact AI/ML technologies are having on geodesy, highlighting both the challenges and opportunities of using these data-driven methods to address the complexities of geodetic data. With the rapid growth in data generated by space-geodetic techniques like Global Navigation Satellite Systems (GNSS), Interferometric Synthetic Aperture Radar (InSAR), and upcoming satellite gravimetry missions, traditional analytical methods are reaching their limitations. AI/ML offers innovative solutions to process and analyze this wealth of information, enhancing the determination of geodetic parameters and providing new insights into Earth's dynamic processes. In response to this rapid evolution, key initiatives have been established to promote AI/ML-driven innovation in geodesy. In 2023, the Global Geodetic Observing System (GGOS) established the Focus Area on Artificial Intelligence for Geodesy (AI4G), which aims to improve geodetic data analysis and product generation through AI, with a focus on interpretability and trustworthiness. In parallel, the Inter-Commission Committee on Theory (ICCT) Joint Study Group T.48 on Theoretical foundations of Machine Learning in Geodesy was formed to advance and refine the theoretical framework for applying ML techniques in geodetic research. The symposium's sessions are closely aligned with these initiatives, encompassing a broad range of geodetic subfields. In this way, the symposium especially seeks to foster cross-disciplinary collaboration within geodesy and beyond. Contributions utilizing AI, ML, deep learning (DL), or other data-driven techniques across all areas of geodesy are highly encouraged, reflecting the growing importance and potential of these methods in advancing geodetic science.

- Session 1: Geodetic machine learning: Theoretical challenges and opportunities for geodesy
- Session 2: AI for Deformation Analysis and GNSS Remote Sensing: Earth, Atmosphere and Natural Hazards
- Session 3: Decoding Earth's Dynamics: Machine Learning Frontiers in EOP and Gravity Field Assessment

J02-1: Geodetic Machine Learning: Theoretical Challenges and Opportunities for Geodesy

Conveners: Lotfi Massarweh, Mostafa Kiani Shahvandi, Alireza Amiri-Simkooei

In recent decades, Machine Learning (ML) has demonstrated significant capabilities in data modeling and prediction across various scientific domains. The field of geodesy has lately seen considerable interest towards adopting ML for geodetic problems. However, the geodetic community is yet to fully understand and embrace ML capabilities. To this end, it is often necessary to adapt the existing ML methods to account for the characteristics of the geodetic data, which include, among others, its physical interpretation and the need for rigorous uncertainty analysis. This session invites contributions that focus on theoretical advancements for geodetic problems based on ML/Deep Learning (DL). We welcome studies that explore the following topics:

- Investigating and developing new ML/DL architectures tailored to geodetic fields
- Physics-informed ML (PIML) for an accurate physical interpretation of geodetic data
- Uncertainty quantification and analysis for ML/DL methods applied to geodesy
- Interpretable ML/DL for advancing the interpretability of the geodetic ML/DL solutions.

Particular interest is given to the theoretical description and application of these newly designed ML/DL paradigms to geodetic data, which cover different techniques and technologies. This session aims at demonstrating the opportunities and challenges of "geodetic ML" methods, focusing on theoretical foundations and algorithmic advancements. These results will provide the geodetic community with a more solid mathematical methodology, and possibly a more critical outlook in the evaluation of such innovative solutions.

J02-2: AI for Deformation Analysis and GNSS Remote Sensing: Earth, Atmosphere and Natural Hazards

Conveners: Milad Asgarimehr, Ashutosh Tiwari, Monique Kuglitsch

Ground movement is tracked using deformation analysis techniques such as GNSS (Global Navigation Satellite System) and InSAR (Interferometric Synthetic Aperture Radar). GNSS remote sensing provides valuable insights into Earth's surface, atmosphere, and environmental processes. This session will explore how Artificial Intelligence (AI) is transforming these geodetic techniques, with applications in Earth and atmospheric monitoring as well as natural hazards. Among many related topics, it will:

- Present AI innovations in processing GNSS and InSAR data to improve Earth and ground movement monitoring.
- Explore AI advancements in GNSS ground sounding, radio occultation, and reflectometry for enhanced retrieval algorithms, surface, tropospheric and ionospheric studies, climate trend analysis, as well as modelling and predictions.
- Highlight AI-driven methodological advances in natural hazards such as earthquakes, landslides, volcanic activity, urban infrastructure (using deformation analysis techniques) and hurricanes, floods, droughts, wildfires and ionospheric extremes (using GNSS remote sensing techniques).
- Identify key challenges and opportunities, and explore future research avenues to enhance AI's role in Earth system monitoring and hazard response using these geodetic techniques.
- Promote collaboration between AI experts, geophysicists, geodesists, and climate scientists to develop integrated approaches to Earth and hazard monitoring.

J02-3: Decoding Earth's Dynamics: Machine Learning Frontiers in EOP and Gravity Field Assessment

Conveners: Sadegh Modiri, Santiago Belda, Fupeng Li, Justyna Śliwińska-Bronowicz, Zhangli Sun

Earth's orientation parameters (EOP) and gravity field variations, driven by mass redistribution in the atmosphere, ocean, and land surface, are fundamental to understanding our planet's dynamics. EOP is crucial for applications ranging from satellite navigation and climate science to deep-space exploration, while time-variable gravity field models derived from GRACE/GRACE-FO missions have significantly advanced our understanding of surface mass changes and global water cycles. Recent advancements in Machine Learning (ML) present great opportunities to enhance traditional methods for assessing both EOP and gravity field changes. This session invites contributions that leverage ML techniques to improve the accuracy, resolution, and timeliness of existing EOP and gravity field products, as well as to reconstruct and predict them beyond the observation period. We welcome research on ML-based methods for EOP prediction, with a particular focus on analyses that elucidate the influence of geophysical and meteorological factors; downscaling, reconstructing, or predicting GRACE/GRACE-FO data; drought and flood early warning; and closing the sea level budget. We are especially interested in physics-informed ML models that integrate gravity data into land surface or hydrological models, providing new insights into water cycle processes. We also encourage contributions that examine the broader implications of these advancements, particularly in understanding how the Earth system responds to anthropogenic actions and global climate change. By combining ML with established traditional and geophysical approaches, this session aims to foster interdisciplinary collaboration and stimulate innovative research.