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Editorial: Next generation visualization and communication systems for earth science using immersive reality and serious gaming

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Editorial on the Research Topic
Next generation visualization and communication systems for earth science using immersive reality and serious gaming

High-variety earth science data is being produced at an increasing volume and velocity to power environmental research, reinforced by the advancements in Internet of Things (IoT) technologies and the widespread deployment of internet-connected sensors (Sermet and Demir, 2022a). Utilizing this enormous data set for context-aware and on-site analysis that is enhanced with realistic visualizations and event dynamics transcends the capabilities and reach of traditional information systems for environmental management (Kolditz et al., 2019). High volume data from diverse sources requires integrated and interactive solutions to allow professionals, academics, decision makers, and the public to perceive the complete picture regarding the consequences of climate change as well as the environmental issues revolving around a community and to discover actionable knowledge upon context-informed analysis (Rink et al., 2020).

Mixed reality and serious gaming present immense potential in earth sciences to overcome the challenges of engaging stakeholders and community members in decision-making and disaster preparedness, communicating huge environmental data within a geospatial context, and simulating non-replicable extreme events for evaluation (Sermet and Demir, 2020). Furthermore, the incorporation of gamification and interaction into data exploration and decision-making for risk reduction and environmental management shows significant potential for participatory planning, collaborative learning, and building conceptual understanding of physical phenomena and processes (Teague et al., 2021).

The primary purpose of this research topic is to encourage the development and evaluation of virtual and augmented reality experiences as well as serious gaming approaches with application in the earth science and water resources domains (Sermet and Demir, 2022b). We intend to attract more attention and shine a light to the potential and utility of key research areas summarized as follows: a) Hydrological data exploration and visualization; b) *In-situ* geospatial visualizations and community scenario simulations; c) Visual analytics tools and workflows for spatiotemporal data; d) Disaster preparedness, mitigation, and recovery; e) First-responder training and emergency response; f) Participatory decision support for shared-vision planning and scientifically informed policymaking; g) Public outreach and educational tools for water resources; h) AI-augmented intelligent and immersive cyberinfrastructures in environmental sciences; and i) Next-generation hydrological information and decision support tools enhanced with immersive technologies. As part of this Research Topic, submitted manuscripts demonstrate the usefulness of immersive reality approaches in some of the aforementioned areas. An overview of these articles are provided below to convey the wide range of applications within this scope.

Kehl et al. investigate visualization design approaches for 4D spatio-temporal data, in particular coupled Eulerian-Lagrangian fluid-flow. Such approaches are particularly useful for the analysis of oceanic processes based on multivariate trajectories and attributes. The authors extensively discuss the design process of contextual, clutter-reduced visualization and evaluate existing approaches with respect to perceptual principles. They introduce a novel color-mapping approach for 3D velocity tensors employing transparency-modulated, coloured image composition. The resulting approach was applied to a plastic-tracing case study, visualizing algae accumulating on the surfaces of marine plastic particles affected by the hydrodynamic velocities in the ocean.

Graebling et al. present a prototype for a Virtual Experiment Information System for the Underground Research Laboratory in Mont Terri, Switzerland. The lab has been operational for over 25 years and a large number of *in-situ* experiments related to the storage of nuclear waste are conducted there. The authors combine a large number of heterogeneous data sets related to those experiments, the lab itself as well as the surrounding geology within an interactive 3D framework based on Unity. The framework features intuitive visualizations of a large variety of data sets that are in part file-based and in part live data loaded from the operational databases of the lab. The approach features both observation and simulation data, enabling complex visualization scenarios such as sensor measurements changes in the context of geological structures and simulation results of saturation- or temperature changes.

Helbig et al. put forth a visual analytics platform that is equipped with a digital twin environment and geovisualization capabilities to allow the investigation of heterogeneous and spatiotemporal data through virtual reality. The immersive application for the analysis of environmental mobile sensor data in an urban context was also built on Unity Game Engine with components for multi-format data integration, performance optimizations, an intuitive GUI and 3D representations, and analytics. Their work showcases how digital twin-based immersive analytics environments can enhance situation evaluation and decision-making due to the potential to integrate sensor data, crowdsourced data, environmental parameters, weather conditions, and routes and infrastructure.

Sajjadi et al. investigates the effectiveness and utility of serious games in environmental sciences education. They created a serious game (i.e. CZ investigator) as well as a static informational website to teach about the Critical Zone (CZ) in order to study the difference in these communication methods in regards to their effectiveness in the educational context within the domain of environmental systems and policies. The game offered a virtual interactive environment that demonstrates the cause and effect and implicit relationships of human actions and environmental responses, such as how crop yield may negatively be affected with groundwater depletion which can be exacerbated by car washes. Their findings indicate that gamification indeed helped increase the participants' understanding and appreciation of the Food-Energy-Water nexus and facilitate systems thinking, allowing the participants to holistically think and evaluate the issues at hand. Given the positive impacts of utilizing a desktop application for the game, it has been contemplated that adding immersive capabilities to such game-based approaches may improve engagement further.

In summation, immersive technologies as well as mechanisms of gamification hold a substantial potential in the prospect of creating the next-generation of decision support and information systems in earth sciences. Although many challenges remain in such technologies and approaches adoption at a wider scale, the literature clearly indicates the feasibility as well as their immense potential justifying further research and development in an interdisciplinary manner.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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