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3D Geovisualizations at Multiple Scales: UAV and VR Integration for Geosite Exploration

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Abstract

Geoparks are areas of significant geological importance, characterized by their diverse formations, scientific value, rarity, and aesthetic beauty. These regions often contain globally important geoheritage sites that capture Earth's complex geological history and the events that have shaped their unique landscapes(Zouros, 2017). Geoheritage mapping plays a vital role in managing and documenting geodiversity, supporting the development and implementation of geoconservation strategies (Coratza et al., 2021). Modern advancements in geographic information systems (GIS) and geological databases have enhanced the mapping and visualization of geoheritage (E. Papadopoulou et al., 2021; E. E. Papadopoulou et al., 2020). The mapping process's scale is crucial, as it determines the visualization's detail, influencing two-dimensional and three-dimensional representations of geological features (Martin et al., 2014).

The emergence of geospatial data collection technologies, such as unmanned aerial vehicles (UAVs), has revolutionized mapping practices (Nex & Remondino, 2014). UAVs provide high-resolution imagery, enabling efficient, repetitive, and safe surveying of challenging terrains. Recent literature elucidates methodologies for 3D mapping spatiotemporal phenomena using UAVs, highlighting their utility across various domains. Underscores UAVs' role in transitioning from localized observations to regional mapping, leveraging Earth-observation data for cost-effective monitoring at a local scale.

Augmented reality (AR) and virtual reality (VR) technologies have introduced new dimensions to geovisualization. AR integrates additional data into real-world environments, while VR provides immersive three-dimensional experiences, increasingly applied in geospatial analysis and land management Vargas et al., 2020). These technologies allow users to explore geological formations remotely, offering innovative ways to engage with geoheritage.

This study explores the integration of high-resolution UAV data with virtual reality (VR) environments to create immersive experiences for Plaka's Park in Sigri, Lesvos Island, Greece. Covering 70 acres, this park features coastal and inland fossil formations. It is notable for its significant plant fossils, including 37 sites with fossilized trees in their original growth orientation, making Plaka's Park a geotope of global importance. The site provides a unique opportunity to observe geological formations and fossil specimens within their geomorphological context. Very high-resolution UAV data suitable for a 1:50 cartographic scale mapping of the geopark, terrestrial imagery at a 1:5 scale for fossil sites, and 360-degree panoramas taken from the ground were used to create and enhance a VR immersive environment. These VR geovisualizations allow users to interactively explore geological sites, gaining insights into their placement, geological significance, and fossilized features. The integration of high-resolution UAV data enhances the visual fidelity and realism of the VR experience, allowing users to navigate to the geosites with unprecedented detail and accuracy. The VR geovisualization application for Plaka's Park was designed to provide an immersive and interactive experience for users exploring the geological and fossilized features of the site. By leveraging a spatial narrative, the application allows users to navigate the park through a virtual map guide based on the original map of the Lesvos Geopark. Focusing primarily on the western section of Plaka's Park, the application highlights ten key fossil sites through two walking routes. Integrated audiovisual media, such as photos, and textual content, enrich the experience by providing detailed insights into excavation findings. Developed using the Unity3D game engine and supported by the HTC Vive Pro VR system, the application ensures compatibility with various platforms while delivering a visually engaging and interactive exploration. Users can explore through interactive icons, objects, and teleportation options for navigating specific excavation sites

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rendered at a 1:1 scale with high spatial precision. The application includes thematic information, visual aids, and intuitive icons for seamless navigation and enhanced user engagement. With its easy-to-use interface and detailed 3D geovisualizations, the VR environment effectively connects physical and digital exploration.

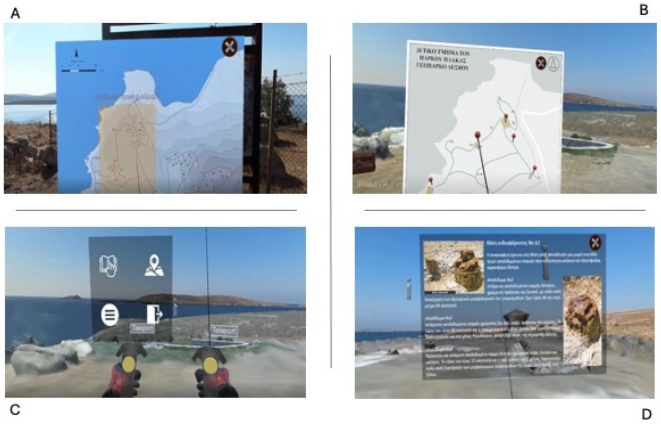

Figure 1. Depictions from Virtual reality environment a) Entrance to Plakas Park with virtual maps presenting the geopark. B) The virtual map is a tool of navigation that provides teleport to the used c) graphical icons acting as application aids (UI elements) d) thematic info for a fossilized place selected by the used. The info is used triggered when within the fossil place.

This study highlights the transformative potential of integrating high-resolution UAV data with VR environments to create immersive 3D geovisualizations of geosites. The proposed methodology effectively emphasizes the critical role of cartographic scale in enhancing the visualization and understanding of geoheritage within VR settings. By leveraging very high-resolution UAV-acquired data, the cartographic outputs demonstrated their ability to deliver precise geovisualizations suitable for interactive, immersive applications. The application of VR geovisualization for virtual tours of fossiliferous sites presents numerous advantages. These include the ability to observe geosites across multiple scales, harness the high resolution of cartographic outputs, and enable interactive engagement with inferred geological insights. Users gain the opportunity to navigate geosites in a detailed, accessible, and realistic manner, breaking physical barriers and fostering a broader appreciation and understanding of geoheritage.

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