

Integrating Laser Scanning, BIM, and Virtual Reality (VR) Technologies for Monitoring and Restoration of Existing Historical Structures

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SUMMARY

Introduction:

Preserving cultural heritage has become a critical global priority, requiring innovative and precise methods to address the challenges of deterioration and historical authenticity. This research pioneers a multidisciplinary approach to cultural heritage conservation, integrating advanced laser scanning technologies, Building Information Modeling (BIM), and immersive visualization using gaming engines. By focusing on a 13th-century Benedictine Abbey in Sieciechów, Poland, this study demonstrates the transformative potential of modern technologies in preserving fragile historical structures.

Motivation and Problem Formulation:

Historical structures worldwide face accelerating risks due to environmental degradation, aging, and human impact. Traditional methods of documentation and conservation often fall short of providing the accuracy or efficiency required for these complex challenges. This project addresses these limitations by combining high-resolution 3D point cloud data from the Leica RTC360 scanner and MS60 Multistation with BIM workflows, enabling precise analysis of structural vulnerabilities like cracks and material losses. The use of Unreal Engine offers an interactive and immersive way to visualize these findings, transforming how stakeholders engage with preservation data.

Innovative Contribution and Global Relevance:

This approach introduces a novel workflow for cultural heritage preservation, highlighting several groundbreaking

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features:

- Non-invasive, detailed structural monitoring using high-precision laser scanning performed at different resolution levels.
- Automated generation of BIM models integrated with immersive virtual environments, enabling real-time comparisons of historical and current states.
- Enhanced accessibility for remote collaboration and decision-making through interactive 3D visualization.

The research aligns with global trends in digitization, sustainable restoration, and the creation of digital twins for heritage management. It contributes to integrating preventive conservation practices, which emphasize early intervention to mitigate damage and prolong the lifespan of cultural sites. Moreover, these innovations complement international efforts, such as those demonstrated in preserving other world cultural heritage sites, e.g., Machu Picchu and Notre Dame Cathedral, where advanced technologies have safeguarded invaluable cultural assets. The investigated project – a 14th-century originating benedictines' abbey in Sieciechów, Poland is entirely in line with this global trend, and the momentousness of the researched historical object is not behind other similar world heritage sites.

Significance and Broader Impact:

Integrating immersive technologies and geospatial precision reshapes the preservation paradigm by making complex heritage data more accessible and actionable. This methodology not only provides a

robust solution for conservationists but also engages the public through virtual heritage tours and interactive educational experiences. By bridging historical authenticity with cutting-edge innovation, this research exemplifies a scalable, globally relevant model for the sustainable preservation of humanity's cultural legacy.

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