The potential of PERCEPTIVE reconstructions in Cultural Heritage for the web3D-technology stack

Holger Graf[a], Sofia Pescarin[b], Bruno Fanini[b], Saptarshi Neil Sinha[a]

[a] *Fraunhofer IGD, Darmstadt, Germany*
[b] *CNR ISPC, , Florence, Italy*
[c] *CNR ISPC, , Rome, Italy*

Abstract

The workshop will cover hybrid experiences in web3D, web3D tools for conservators and heritage science experts, assessing visitor behaviors, open standards in public exhibitions, and integrating AI technologies for improved visual perception, along with specific techniques such as cross-spectral 3D reconstruction, semi-automatic segmentation, semantic style transfer, and appearance modeling. Web3D technologies provide interactive ways to present scientific data, including 3D models from archaeometric surveys, and offer new possibilities for accessing and examining artwork. We will present a Web3D/WebXR tool for inspecting multi-layered 3D assets, enabling interactive discovery, semantic enrichment, and efficient spatial queries. The tool also integrates AI-generated material assets into the web3D technology stack, enhancing applications and enabling immersive material reconstructions for cultural heritage experts and researchers.

1. Introduction

Integrating AI technologies into the web3D technology stack enhances the reproduction of 3D assets in cultural heritage, improving reconstructions and enabling material estimation, lighting simulation, and style transfer. Web3D technologies also enable the creation of interactive tools for presenting scientific data and visualizing 3D models obtained from archaeometric surveys. Leveraging Web3D/WebXR, experts and the public can explore and analyze cultural artifacts directly in web browsers. We will present the tools we have developed [1], which utilize AI to create a Web3D/WebXR tool based on the ATON framework [2] for multi-layered 3D exploration. These tools also incorporate immersive analytics in WebXR, facilitating collaborative inspection and discussion of interaction patterns within immersive 3D spaces.

2. AI based technologies for PERCEPTIVE reconstructions

Integrating AI technologies into the web3D technology stack can enhance the reproduction of perceptive 3D assets in the field of cultural heritage by improving photogrammetry based spectral 3D recontructions, material reconstruction, lighting simulation, and style transfer.

2.0.1. Cross-spectral 3D reconstruction from multi-view spectrum-maps

Radiance field-based 3D reconstruction using Neural Radiance Fields (NeRFs) [3] and 3D Gaussian splatting (3DGS) [4] achieves photorealistic scene reconstruction from multiple-view images. A unified cross-spectral scene representation [5, 6], obtained through correlation analysis between spectra, enables comprehensive information querying across different spectra, leading to a deeper understanding of natural processes. This approach can also be applied to color reconstruction in cultural heritage, allowing accurate reproduction of colors in artifacts and artworks.

2.0.2. Semi-automatic segmentation using foundation models

Utilizing foundation models like SAM [7] enables automated segmentation of diverse scenes, which can be improved by refining predicted segments and applying them to multi-view images using tracking algorithms like DEVA. This approach generates segmentation atlases and supports image-based segmentation of 3D models.

2.0.3. Semantic style transfer

Applying style transfer to multi-view images and using resulting style atlases with segmentation maps enhances the visual aesthetics and realism of 3D models, particularly for recolorization of cultural heritage objects based on iconographic evidence.

2.0.4. Appearance modelling and estimation

Extending NeRFs [8, 9] and 3DGS [10] to estimate materials and lighting enables lightweight appearance capture and relighting, valuable for realistic reconstructions of cultural heritage objects with changing appearances. This advancement creates accurate and visually appealing digital representations of CH objects.

3. Web3D for conservators

Web3D technologies and standards nowadays allow to craft rich and interactive tools to present scientific data. The visual-

ization of 3D models acquired from archaeometric surveys on ancient statuary have become a fundamental aspect in digital preservation, as well as the development of innovative scientific applications and interaction models to discover original colors (ancient polychromy) or manipulate and compare multiple hypotheses. The possibility to exploit Web3D/WebXR to inspect and compare analytical data layers directly on the digital 3D replica, right inside the web browser, can provide experts and general public with new ways to access and examine the artwork. Interactive Web3D presentations of 3D assets with multiple scientific layers associated, require accessible, functional, engaging and expressive discovery approaches. Within the context of our work [1], a Web3D/WebXR tool based on the open-source ATON framework [2] is being designed and developed, investigating:

- modular architectures to load and inspect multi-layered 3D items directly from cloud systems
- interactive, multi-layer discovery based on interactive lenses metaphores [11] extended with a dictionary of custom shapes
- semantic enrichment through punctual annotations (spot analysis) and filtering via UI
- efficient spatial queries of encoded semantic masks and their use for color or material manipulation
- interactive painting on multiple atlas spaces, operating on lightweight 2D data
- XR presentation and spatial interfaces, allowing users immersive and engaging models to discover multiple layers through AR/VR (WebXR)
- extensible controllers allowing the tool to interact with external interfaces

4. Next steps/Open questions

4.1. Integration of cross-spectral 3D reconstructions

Sparse cross-spectral scene reconstruction plays a crucial role in multiple applications such as smart farming, document analysis, defect detection, and cultural heritage preservation. It enables conservators to effectively analyze and interpret cultural heritage objects. In this context, we will provide recommendations and explore the possibilities of integrating it into the Web3D technology stack. Although it does not offer complete spectral rendering, it can assist in visualizing 3D reconstructions of a specific spectra generated through AI or non-AI methods.

4.2. Easy access to AI generated material assets for Web3D experiences

The integration of deep learning-generated material assets into the web3D technology stack offers the possibility of accessing realistic materials estimated by deep learning algorithms. This integration has potential applications in industrial design, synthetic data generation, cultural heritage preservation etc. In the field of cultural heritage it becomes easier for conservators to visualize immersive and visually appealing material reconstructions without the need for complex setups.

4.3. Analyzing users interactions through Web3D tools

Capturing large amounts of users' sessions performed through remote 3D applications may provide crucial insights for the detection of interaction patterns. Emerging Immersive Analytics [12],[13] Web3D/WebXR tools exploit recent web technologies to bring visual data analysis into a physical or virtual space, accelerating or supporting online workflows related to the study and analysis of interactions.

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