# Data-driven Techniques for Immersive WebXR Exploration of Indoor Spaces from Monocular 360 Input

Marco Agus*
magus@hbku.edu.qa
College of Science & Engineering,
Hamad Bin Khalifa University
Doha, Qatar

Giovanni Pintore
giovanni.pintore@crs4.it
CRS4
Cagliari, Italy
National Research Center in HPC, Big Data and Quantum Computing
Italy

Enrico Gobbetti
enrico.gobbetti@crs4.it
CRS4
Cagliari, Italy
National Research Center in HPC, Big Data and Quantum Computing
Italy

## Abstract

Capturing and exploring common indoor environments, such as homes, offices, or public buildings, is essential across fields like architecture, civil engineering, urban planning, and real estate. In this context, 360° imagery is attracting lots of interest, since it offers a cost-effective solution for wide scene coverage in a single shot and, when viewed through Head-Mounted Displays (HMDs), it naturally supports 3D exploration via head movements. However, a single panorama remains a flat and static representation. To overcome these limitations, recent efforts in artificial intelligence (AI) have been devoted to the problem of generating editable, immersive 3D representations from a single 360° image. This tutorial presents state-of-the-art techniques for AI-driven scene reconstruction, virtual styling and staging, and their integration into immersive applications using WebXR, supporting stereoscopic vision and motion parallax on standard VR headsets.

## CCS Concepts

• **Computing methodologies** → **Graphics systems and interfaces**; **Scene understanding**; **Neural networks**; • **Human-centered computing** → **Virtual reality**; **Web-based interaction**.

## Keywords

Panoramic Indoor Scenes, Virtual Tours, WebXR, Immersive systems, Novel View Synthesis

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*Corresponding author.



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## 1 Tutorial authors and presenters

- **Marco Agus** (co-author and presenter) is an associate professor at Hamad Bin Khalifa University (HBKU), Qatar. He previously held research roles at KAUST, Saudi Arabia, and CRS4, Italy. He earned his M.Sc. and Ph.D. from the University of Cagliari, Italy. His research spans many visual computing domains, including visualization, virtual reality, and machine learning for vision and graphics. He has published over 50 peer-reviewed papers and taught at major venues like CVPR, 3DV, ACM SIGGRAPH, and Eurographics. He also serves regularly as a reviewer, chair, and editor for top conferences and journals.
- **Giovanni Pintore** (co-author) is a senior researcher at CRS4, Italy, and affiliated with the Italian National Research Center in HPC and Quantum Computing. He holds a Ph.D in Computer Science from the University of A Coruna, Spain. His work focuses on computer graphics and vision, with recent interests in deep learning, panoramic image processing, scene understanding, 3D reconstruction, and immersive scene exploration. He has published widely in top venues and journals like SIGGRAPH, EUROGRAPHIS, CVPR, ECCV, ISMAR, TOG, and CGF, and taught courses at SIGGRAPH, SIGGRAPH Asia, EUROGRAPHICS, 3DV, and others. He actively contributes to the research community through conference committees and executive boards.
- **Enrico Gobbetti** (co-author and organizer) is the director of Visual and Data-intensive Computing at CRS4, Italy, and affiliated with the Italian National Research Center in HPC and Quantum Computing. He holds a Ph.D. in Computer Science from EPFL. Switzerland, and has held positions at EPFL, UMBC, USA, and NASA/CESDIS, USA. At CRS4, Enrico develops and manages a research program in visual and data-intensive computing supported through institutional, industrial, and government grants, including many national and international collaborative projects. His research, widely published in major journals and conferences, primarily focuses on improving the acquisition, creation, processing, distribution, and exploration of complex and/or massive datasets and real-world objects and environments. He actively contributes to the scientific community through editorial boards, conference chairing and committee participation, and working groups. He is a Fellow of the Eurographics Association.

## 2 Subjects Covered

- Overview of panoramic indoor imaging, 3D reconstruction priors, and needs of immersive applications
- AI-driven room modeling and floorplan estimation from monocular 360° imagery
- Data-driven pipelines for semantic-aware depth and layout inference
- Visual editing and view synthesis from single panoramas
- WebXR integration for immersive multi-room exploration
- Demonstration of recent research results and tools.

## 3 Learning Objectives

Participants will:

- Understand the challenges and opportunities of AI-based structured reconstruction from panoramas
- Learn about the role of data-driven, semantic and geometric priors in scene understanding
- Gain practical knowledge of WebXR tools for immersive applications
- Understand constraints and trade-offs of pipelines that enable 3DOF immersive navigation and editing starting from a single image
- Review current research trends and explore open problems in indoor modeling and editing

## 4 Intended Audience

This tutorial targets graduate students, researchers, and developers in the fields of computer graphics, computer vision, 3D web, and extended reality (XR). It is also relevant to professionals in architecture, real estate, and digital twin applications who wish to understand the possibilities of present and future immersive AI-driven modeling systems.

## 5 Prerequisites

Attendees should have a basic understanding of computer vision, 3D graphics, and deep learning. Familiarity with immersive systems or XR concepts is helpful but not required.

## 6 Level of Difficulty

Intermediate. The tutorial is designed to be accessible to participants with a general technical background in visual computing, while still offering detailed insights into cutting-edge techniques and tools.

## 7 Related material

The content of this tutorial is based on the authors' experience on several relevant topics. A comprehensive review of the 3D indoor reconstruction domain was published in Computer Graphics Forum [6], and subsequently presented at Eurographics 2020 and in a half-day SIGGRAPH 2020 tutorial [10]. A CVPR 2023 course and a SIGGRAPH Asia 2024 course [3] focused on omnidirectional imagery and covered both reconstruction and exploration. This tutorial builds upon these previous efforts, with a particular focus on editing and exploration techniques using WebXR. These prior courses and surveys form a solid foundation for the presented material and can serve as supporting documentation. We also highlight complementary surveys, such as those on panoramic scene understanding [2] and 3D geometry extraction from 360° images [1], to provide a more complete view of the field.

On those topics, the authors have introduced several research techniques that will be used as examples in this course. These include deep learning–based approaches for scene synthesis [8], depth estimation and completion [5, 7],automatic scene emptying [4], joint extraction of geometry, material, and semantic information [11], as well as XR exploration [8, 9, 12] and photorealistic style transfer between indoor scenes [13], among others.

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