Capstone Project Showcase

Real-Virtual Synchronized Lighting Adjustment System

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Abstract

We present an XR lighting system on Meta Quest 3 that synchronizes virtual and physical space. Using Meta XR Scene Understanding for scene meshes. Real-time illumination is computed in Unity URP with custom HLSL. Users place, move, and tune luminaires via gestures or controllers, instantly visualizing effects on reconstructed geometry for rapid what-if evaluation.

Architecture

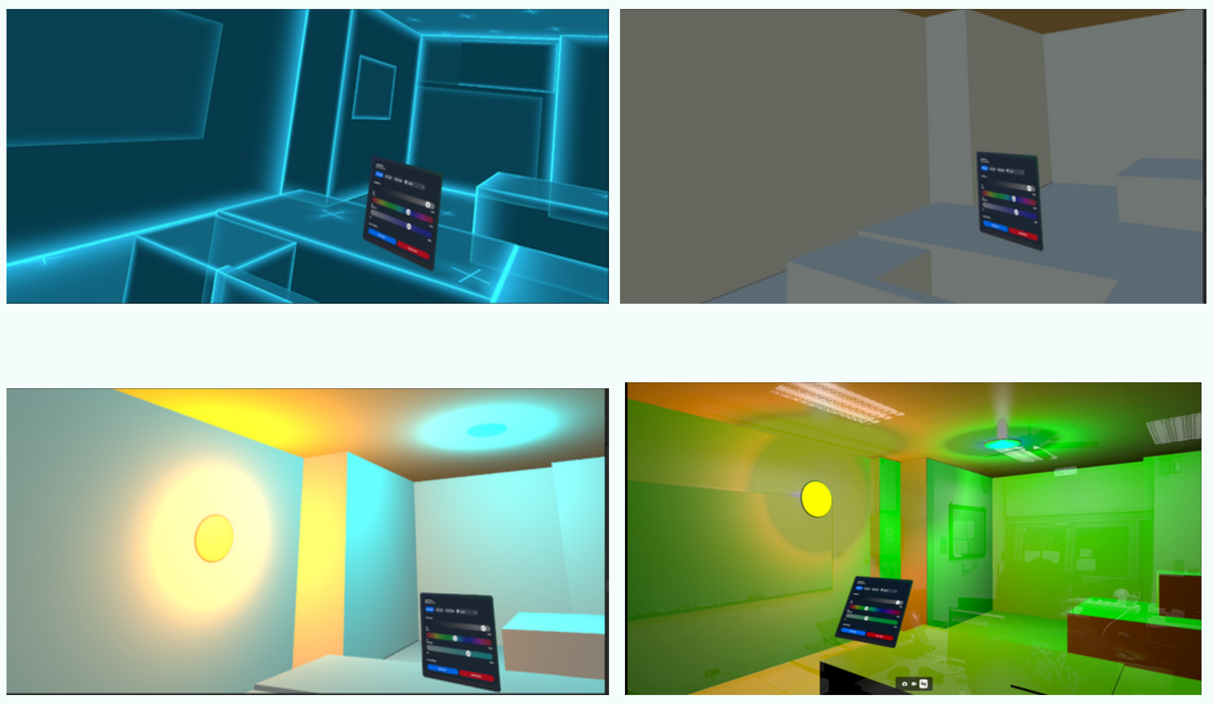
Environment Geometry Acquisition

Using the Scene component of Meta MR Utility Kit (MRUK), we first capture a JSON scene description of the current room—covering furniture, walls, and ceiling—and then convert it into meshes.

URP Rendering process

Because the default MRUK shaders (Fig. 1–2) do not support our requirements, we implemented custom URP shaders in HLSL and split the room mesh into two passes: shadow-casting layer and light-receiving layer.

The light-receiving layer aggregates illumination from multiple sources (Fig. 3) and is set to semi-transparent so the real environment remains visible. Since transparent materials typically cannot cast shadows, we added a transparent, light-occluding shadow-caster shader dedicated to the shadow-casting layer (Fig. 4).



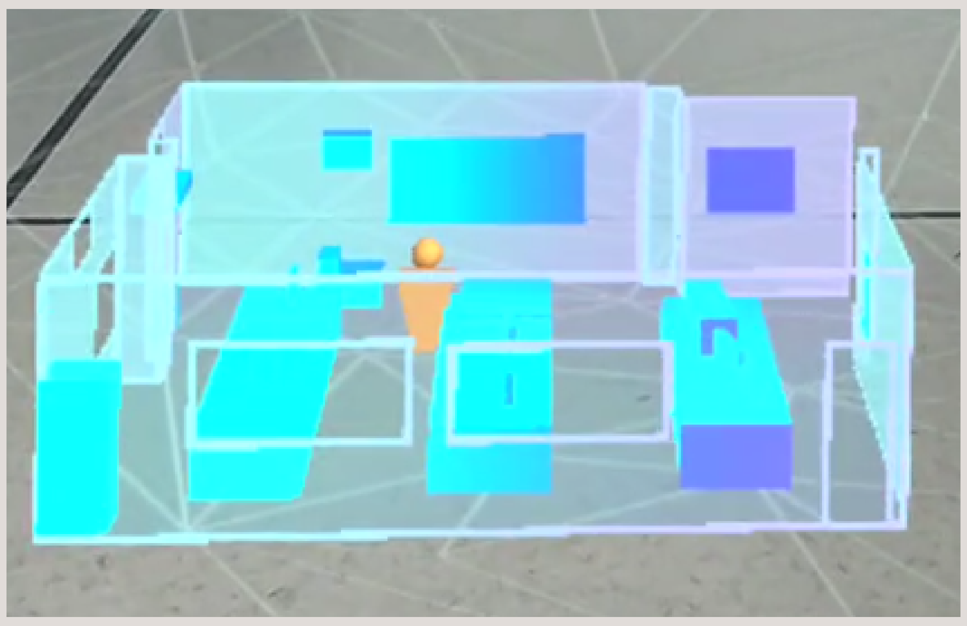
UI & Interaction

The interface uses Ray and Poke interactions to operate sliders and buttons, enabling editing of luminaire position and count, adjustment of Brightness (Value), Hue, and Saturation, and group control for simultaneous tuning of multiple lights.

Lamp Synchronization / Control

The system samples HSV slider values in real time, encodes them as the bulb's JSON API payload, and transmits over Wi-Fi to IoT smart bulbs for synchronized control.

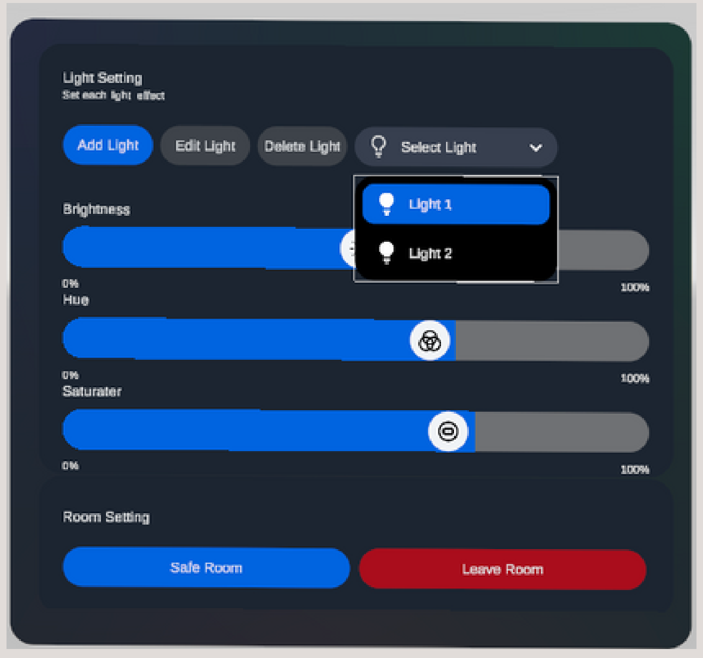
Results



↑ Scene Mesh Generation

↑ WiZ Bulb Synchronized Control

↑ Virtual Illumination Rendering (URP)



↑ Room-Editing Interface

↑ Demo Video

Future Plan

Incorporate material and texture parameters (e.g., metallic and roughness) on the room mesh to enhance the realism of virtual illumination; expand luminaire types and enable users to scan fixture appearances and customize specifications (lumens, CCT, wattage). The system will also support saving/loading room configurations and scene presets for one-click setup, with ongoing optimization of the UI interaction experience. Ultimately, we aim to deliver an immersive lighting simulation platform for aesthetic education and research.