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A DIGITAL TWIN BASED APPROACH TO SMART LIGHTING DESIGN

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ABSTRACT

Lighting has a critical impact on user mood and behavior, especially in architectural settings. Consequently, smart lighting design is a rapidly growing research area. We describe a digital twin-based approach to smart lighting design that uses an immersive virtual reality digital twin equivalent (virtual environment) of the real-world, physical architectural space to explore the visual impact of light configurations. The CLIP neural network is used to obtain a similarity measure between a photo of the physical space with the corresponding rendering in the virtual environment. A case study was used to evaluate the proposed design process. The obtained similarity value of over 87% demonstrates the utility of the proposed approach.

1 INTRODUCTION

As smart lighting technology progresses, the ability to simulate and visualize its potential impact within environments prior to construction is increasingly important. The primary goal of our research is establishing an immersive virtual reality (VR) system to simulate a given physical environment, empowering near-identical smart lighting design within a digital twin (Mohammadrezaei and Gračanin 2022). The system supports real-time changes to lighting fixture settings such as brightness, color, and temporality, such that users are able to interact with the lighting system in the digital twin and witness the impact of those changes to lighting settings immediately. We describe a systematic approach that users can follow to create their own digital twin of a real-world, physical environment (Figure 1). (Figure 1). The users are guided on how to use hardware devices to capture details of the real-world environment for which they would like to produce a digital twin. These details include lighting values of bulbs, furnishing, and dimensional measurements of the environment and its contents. We use real-time lighting to show the impact of changes to brightness,

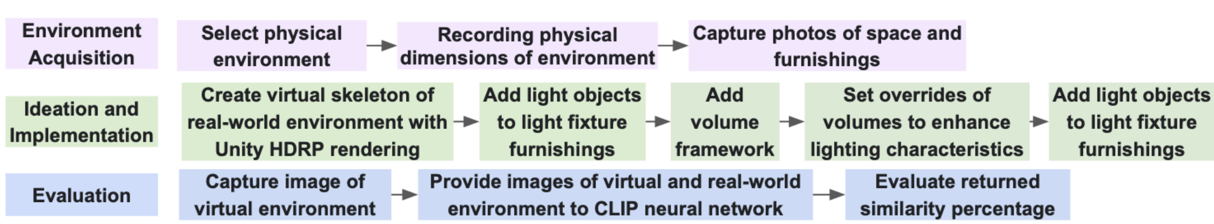

Figure 1: A diagram of our digital twin system approach.

color and temporality immediately, instead of a static, 'baked' environment that requires re-rendering when a lighting value is updated. This provides the existing benefits of physical and hybrid-based lighting so that users receive immediate feedback on lighting setting changes on their digital twin the same as the real-world equivalent.

2 RESULTS

To validate our digital twin's similarity to our photo capturing the real-world office, we generated three renderings: one with missing furniture and incorrect lighting color via the emission temperature setting, one with no local volumes to reflect, refract, blend light and create shadows, and the final one with optimal volume, furniture, and lighting values. As we enhanced the scene to get the digital twin's lighting to match the lighting of the real environment, the returned similarity value increased (Table 1).

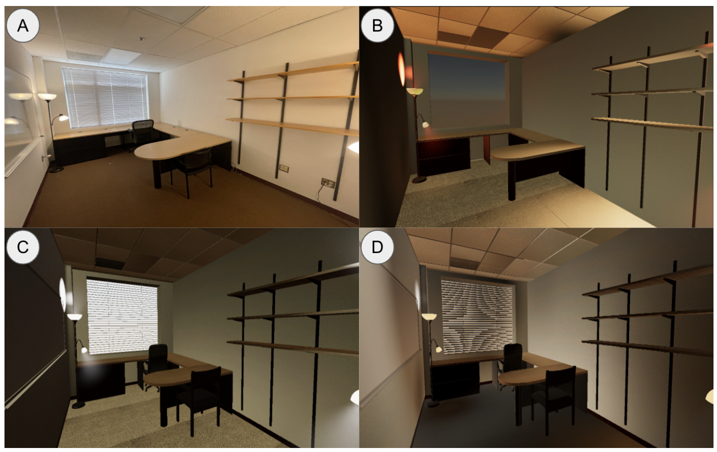

Figure 2: **A:** Photo of the real-world, physical office space. **B:** Rendering with missing furniture and incorrect lighting values. **C:** Rendering with no volumes to reflect light. **D:** Rendering with optimal volume, furniture, and lighting values.

Table 1: Digital twin similarity scores per lighting condition change.

Figure 2	Description	CLIP Similarity Percentage
B	Incorrect lighting and missing furniture	77.168
C	Missing Volume framework	78.427
D	Final Digital Twin	87.665

3 CONCLUSION

We described a digital twin-based approach to smart lighting design that provides designers with a way to evaluate the visual impact of light sources and fixture configurations in architectural settings. Users can use head-mounted displays to fully immerse themselves in a virtual environment, explore different light designs and accurately evaluate the visual outcomes. We believe our case provides a novel contribution to this rapidly growing research area.

REFERENCES

Mohammadrezaei, E., and D. Gračanin. 2022, 26 June–1 July. "Extended Reality for Smart Built Environments Design: Smart Lighting Design Testbed". In *Distributed, Ambient and Pervasive Interactions. Smart Environments, Ecosystems, and Cities: 10th International Conference, DAPI 2022*, edited by N. A. Streitz and S. Kanomi, 181–192. Cham: Springer.