Public summary

Humans spend considerable time indoors, where lighting conditions often are static. This is in stark contrast to the dynamic character of the lighting one experiences when being outdoors. Recognizing the appeal and effects of dynamic natural lighting, there's a growing interest in recreating these dynamic conditions indoors. However, questions remain on understanding how to effectively incorporate this dynamism in indoor lighting. Recent research has focused on understanding the perception of dynamic luminous patterns of natural lighting, such as the shadows of sunlight being filtered through leaves swaying in the wind. Such luminous patterns have been associated with positive perceptual responses such as visual interest, mood, and stress restoration, making their integration indoors an intriguing design objective.

To develop indoor lighting solutions capable of creating dynamic luminous patterns that are perceived as perceptually pleasant, a deep understanding of the properties of dynamic luminous patterns of natural lighting that cause certain perceptual responses is required. The various characteristics of natural lighting, including dynamic spatial and temporal features, add complexity to the task of identifying these properties. To guide the development of indoor lighting solutions, various experiments are needed to identify which properties of dynamic luminous patterns of natural light cause a certain perceptual response. To conduct such experiments, precise control over the lighting conditions within an environment and consistent conditions across a large group of study participants are essential. However, achieving such control with real-world natural lighting is challenging due to its inherent uncontrollable and dynamic nature. Immersive virtual reality (VR) offers a promising solution by providing complete control over the environment, including lighting conditions. Creating VR environments for lighting research demands accurate simulation of the lighting conditions. Radiance, a physically based lighting simulation program regarded as the fundamental platform in the scientific community, is a viable option. However, generating environments with dynamic luminous patterns can only be achieved by a time-consuming and laborious process. Moreover, while Radiance has been validated for various applications, its use for creating VR environments with dynamic luminous patterns of natural lighting is a novel application, making its accuracy uncertain. To address these challenges and facilitate researchers, an accurate and practical simulation tool is needed.

This EngD thesis presents RADYNVR (Radiance Dynamic Virtual Reality), a Radiance-based simulation tool for creating VR environments with accurate dynamic natural lighting. Two methods were developed and implemented for generating dynamic leaf geometry, replicating the movement of leaves swaying in the wind. To accurately and efficiently simulate the luminous properties of patterns of natural light, a novel method for simulating solar penumbras and pinhole projections was developed, validated, and implemented. Additionally, several optimizations were developed and implemented to assist the modeling and streamline the simulation process of dynamic VR environments. The tool is structured as a collection of programs, offering users the flexibility to adapt the tool as a complete pipeline or utilize individual components based on their needs. The tool features bi-directional integration with Radiance, ensuring access to Radiance's vast capabilities, while also facilitating future developments. For researchers, the tool provides an accurate and straightforward method to create VR environments that can be used to conduct experiments on the perception of, and responses to, dynamic luminous patterns of natural light. In the evolving landscape of advancing VR technology, RADYNVR presents itself as an important first step for utilizing Radiance-based methodologies for VR lighting studies.

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