# IMMERSIVE ENVIRONMENT LIGHTING USING LIGHT PROBES

## Using a 360 Camera for Realistic Lighting in AR/MR

Sanjay Sankaran
University of Washington


## ABSTRACT

Augmented and Mixed Reality (AR/MR) applications often struggle to integrate virtual objects seamlessly into real-world environments. One major challenge is realistic lighting—virtual objects must match the illumination of their surroundings. In this project, we use a 360-degree camera as a light probe to capture real-world lighting conditions and apply them to virtual scenes in real-time. By estimating emissive properties from the environment, we create more immersive AR/MR experiences where virtual objects blend naturally with their surroundings.


## INTRODUCTION

Augmented and Mixed Reality (AR/MR) applications often struggle with accurate environment lighting, making virtual objects appear out of place. In real-world scenes, light interacts with objects in complex ways, and without proper lighting estimation, digital objects fail to blend convincingly into physical environments.

This project explores an approach to immersive environment lighting using **light probes**, where a **360-degree camera** captures an environment's lighting conditions. Instead of traditional HDR processing or light source extraction, the captured equirectangular images are directly used after a postprocessing step (blurring). This provides real-time lighting estimation for virtual scenes in AR/MR applications.

## CONTRIBUTIONS

○ Developed a **real-time lighting estimation pipeline** for AR/MR using a **360-camera as a light probe**.

○ Implemented a **custom graphics pipeline in Vulkan** for rendering AR/MR scenes with realistic lighting.

○ Integrated a workflow using **libcurl and Open Spherical Camera** to fetch images from a **Ricoh Theta SC2**.

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## METHOD

The core idea is to use a **360-degree camera as a light probe** to estimate ambient lighting for AR/MR applications. Instead of reconstructing light sources explicitly or performing HDR-based tone mapping, this method **uses the raw equirectangular image directly** with a **blurring postprocessing step**.

The pipeline consists of the following steps:

○ Capture a **360-degree image** using the Ricoh Theta SC2.

○ Retrieve the image using the **Open Spherical Camera API** and **libcurl**.

○ Apply **blurring to the equirectangular image** to approximate indirect lighting.

○ Feed the processed image into a **Vulkan-based graphics pipeline** for real-time rendering.

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## IMPLEMENTATION DETAILS

This project was implemented using the following hardware and software stack:

Hardware:

○ **360-Camera:** Ricoh Theta SC2

○ **Computing Device:** Laptop

○ **Headset:** Kit-provided AR headset

Software:

- Custom-built **C++ application**
- **Vulkan** for real-time rendering
- **libcurl/Open Spherical Camera API** for fetching images from the camera

## APPLICATION ARCHITECTURE

The application has the following moving parts:

- Vulkan Renderer
    - Compute Pipeline: postprocessing
    - Graphics Pipeline: draws/shades objects
- Streaming HTTP Client: Decodes a stream from the spherical camera to the vulkan renderer

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## EVALUATION OF RESULTS

To assess the effectiveness of the lighting approach, we evaluated:

- **Visual Realism**: How well virtual objects blended into real-world environments.
- **Performance**: The impact of real-time lighting on frame rates.
- **Accuracy**: Comparison with traditional lighting estimation methods.

Initial results show that using **360-degree environment lighting** significantly improves the realism of virtual objects in AR/MR. However, **real-time performance** is affected by the resolution of the input image and the blurring process.

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## DISCUSSION OF BENEFITS AND LIMITATIONS

**Benefits:**

- Uses **real-world lighting data** for **accurate shading**.

- Works in **real-time** without complex HDR processing.
- Integrates well with existing AR/MR rendering pipelines.

**Limitations:**

- Blurring can lead to **overly diffuse lighting**, reducing contrast.
- Requires a **360-camera**, which may not be practical for all users.
- Performance depends on **image resolution and processing speed**.

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## FUTURE WORK

Future improvements could include:

- **Dynamic image resolution adjustment** to balance quality and performance.
- **Advanced filtering techniques** beyond simple blurring for better light estimation.
- Integration of **real-time light adaptation**, updating lighting as the user moves.

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## CONCLUSION

This project demonstrates that using a **360-camera as a light probe** can significantly enhance **realism in AR/MR** applications. By using a **simple postprocessed environment map**, virtual objects blend better into real-world environments. While there are **limitations in performance and accuracy**, future improvements could make this a **viable solution for real-time mixed reality lighting**.

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## REFERENCES

[1] Vulkan API Documentation - https://www.khronos.org/vulkan/

[2] Ricoh Theta SC2 API Documentation - https://api.ricoh/docs/theta-web-api-v2.1/