Synthesizing Relative Radiance for Realistic Rendering of Virtual Objects in 3D Photo Collections

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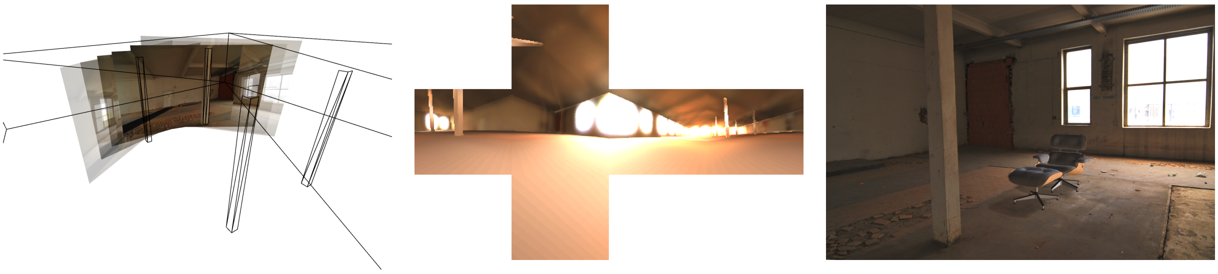

Figure 1: *With a given 3D Photo Collection and scene geometry (left) the relative radiance of the scene is reconstructed (middle), which is used to to apply authentic lighting on virtual furniture embedded in the 3d Photo Collection (right).*

Abstract

We present a novel approach for accurate reconstruction of relative radiance of every surface in an augmented image-based 3D scene. By using unordered images with varying exposure of 3D Photo Collections and a 3D mesh of the scene geometry, the relative radiance of all surfaces in the scene is reconstructed with High Dynamic Range. This is performed by subdividing the surfaces of the scene into patches and calculating the HDR image estimate for each patch. The result is used to embed virtual objects into 3D Photo Collections with authentic lighting.

Categories and Subject Descriptors (according to ACM CCS): I.3.3 [Computer Graphics]: Picture/Image Generation—Display algorithms

Achieving an authentic impression for the augmentation of photos with virtual objects holds several open issues like occlusion problems, render quality adaptation and illumination adaption of the virtual objects to the photos. This paper is focused on the issue image-based illumination. In contrast to a single image, a set of several photos can be used to easily and efficiently build a 3D world (named 3D Photo Collection), e.g. by a tool like Bundler [Sna08] or Photosynth [Mic08], which provides reconstructed intrinsic and extrinsic camera parameters for each photo. This 3D world contains photos as 3D image planes and each photo contains lighting information of the real scene. In conclusion this poses the question how this 3D scene information can be used for a photorealistic illumination of embedded virtual objects.

The goal of this work is to illuminate virtual objects photorealistically in augmented 3D Photo Collections. These objects will be illuminated in a novel image-based lighting technique by automatically synthesizing relative radiance for the given scene geometry.

In [Deb05] a real-time capable approach for image-based lighting was presented. This work has strong restrictions for generating an environment map from photos. Photos of reflective spheres have to be used. So this approach cannot be used in our concept to work with 3D Photo Collections. In [KNBG09] and [NGBA10] we presented another approach for image-based lighting by using 3D Photo Collections. The positions and orientations of the photos inside the 3D Photo Collections were used to determine an approx-

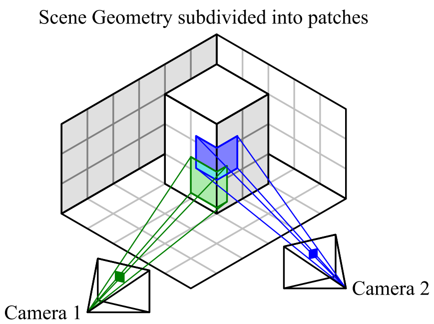

Figure 2: *Projection of images on patches of scene geometry*

imated 3D scene geometry. Hence, the light ray positions could not be exactly determined, an approximation was used. This resulted in errors of the reconstructed, reflected light of closest surfaces. In our new approach the illumination situation of the scene is reconstructed exactly by using the given 3D scene geometry.

To illuminate virtual objects the light that is reflected or emitted by each surface of the real scene needs to be captured. This can be done by projecting the images on the 3D geometry of the scene (see fig. 2), because the underlying 3D Photo Collection provide the known camera parameters. There are already several existing approaches for automatically reconstructing 3D scene geometry from Photo Collections [FCSS10] [FP09]. However, these approaches either make assumptions on the scene geometry that may not be true or the resulting 3D data is not accurate enough for image projection. Instead, we assume a preexisting 3D mesh that is already placed correctly into the 3D Photo Collection. The faces of the 3D scene mesh are subdivided into patches. Each patch stores the collected light as relative radiance.

For each patch p its relative radiance value r_p is calculated as Robertson's HDR image estimate [RBS03]. This is done for all image pixel values y_{ip} that are projected into patch p:

$$r_p = \frac{\sum_i w_{ip}\, t_i\, I_{y_{ip}}}{\sum_i w_{ip}\, {t_i}^2} \qquad (1)$$

Each pixel value y_{ip} is linearized by the reconstructed camera response function $I_{y_{ip}}$ and scaled by its image exposure time t_i and the weighting function w_{ip}.

This approach guarantees to consider all available image information for each patch. The more images with varying exposure times are available for a patch, the more precise relative radiance of a patch will be reconstructed. Thus, in order to get good results, it is important to have a high image density for patches representing the main light sources in the real scene.

The result is the reconstructed relative radiance for each surface of the scene. This radiance data can be processed with standard IBL-techniques. For any position in the scene, a radiance environment map can be created (fig. 1b), which can be used for extracting directional light sources, calculating spherical harmonics coefficients or rendering specular reflections.

To increase performance, our implementation is optimized for modern graphics hardware so all steps can be run on the GPU. The radiance data of all patches is stored as floating point texture and shaders are used to project the images and calculate the HDR image estimate. Shadow mapping prevents projecting image content on occluded surfaces. Fig. 1 shows the implemented scenario of an interior planning tool visualizing virtual furniture in a 3D Photo Collection. The virtual 3D models are illuminated by directional lights that were calculated from the reconstructed radiance data. In our future work we want to extract radiance by estimating the depth of image contents instead of projecting images.

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