An optical system for single image environment maps

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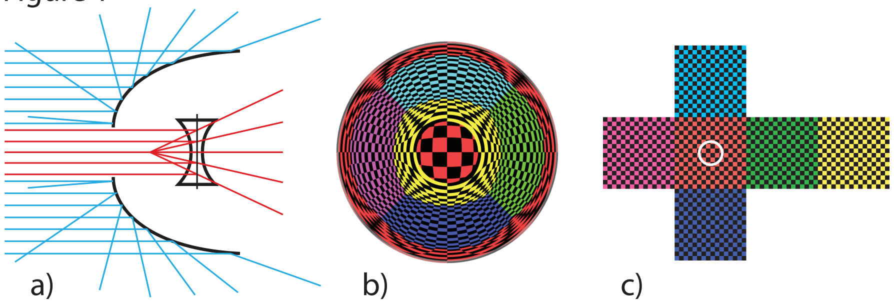
Figure 1



HDR environment maps used for image based lighting are commonly captured using reflective spheres. Other approaches include parabolic reflectors for dual paraboloid maps, 180º fisheye cameras for dual fisheye maps, six wide-angle images forming a cube map, or free-form panoramic stitching of an arbitrary number of images. The reflective sphere approach has one clear advantage: it allows capture of the full environment in a single snapshot, using an ordinary camera. This is particularly important for video applications. However, there are two problems with the reflective sphere approach:

1. The sampling gets progressively worse near forward-facing directions.
2. There is a blind spot behind the sphere.

We propose an optical system which solves both of these problems by using a combination of a convex reflective surface and a lens. The reflective surface is a swept profile that generates a mapping with a uniform sampling density in the radial direction, similar to that of a fisheye lens. The forward-facing directions, the region where the sampling is bad and where the blind spot is located when using a reflective sphere, are imaged by a negative lens placed in a hole at the center of the reflector.

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A cross-section sketch of this optical system is shown in Figure 1a. The resulting image contains the entire 360º field of view, as shown in Figure 1b and Figure 2. The schematic environment used for Figure 1b is shown as a cube map in Figure 1c. The only remaining blind spot is where the camera blocks the back-facing view.

The sampling exhibits good uniformity: the image is oversampled at the inner and outer rim of the mirror, but never undersampled. By allowing a small overlap between the fields of view of the mirror and the lens, a seamless stitching can be achieved. Resampling to a latitude-longitude panorama reveals no undersampling artifacts or blind spots, as demonstrated by Figure 2.

Figure 3 demonstrates the performance of a mirror sphere image. The resampling to a latitude-longitude panorama reveals the undersampling problems near the rim of the sphere and the blind spot behind it.

Figure 4 highlights the regions where the sampling is most non-uniform for each of the methods. Our approach has radially uniform sampling but exhibits oversampling in the green regions. This is not a critical problem, and Figure 2 shows that it does not introduce artifacts. The spherical mirror, on the other hand, has strongly non-uniform radial sampling and is severely undersampled in the red region, leading to the bad quality apparent in the detail of Figure 3.

Figure 2: our system

Figure 3: mirror sphere

Figure 4: sampling non-uniformity