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Eliminating artifacts when inverting visual reverebrations

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Abstract

Reference [1] approximates the imaging model as orthographic. This report describes a consequence of perspective, when compared to the orthographic approximation. Slight misalignments are created between the true visual reverberations, and the shifts of the δ functions used in the recovery filters of Ref. [1]. The result is that reconstruction of $L_{\rm r}$ as presented in Sec. 6.2 of Ref. [1] contains weak residual edge artifacts. We present here a method that overcomes these artifacts. It is based on a variation of the method of [2] for eliminating inconsistent edges.

1. Perspective

Reference [1] approximates the imaging model as orthographic. We now describe a consequence of perspective, when compared to the orthographic approximation. Fig. 1 illustrates two possible paths of light rays originating from object $L_{\rm r}$. The first path is termed *path 1*: rays taking this path hit the *front* interface of the window, and reflect to the camera, where they create an image. The second path is termed *path 2* in Fig. 1. Rays taking *path 2* hit the *back* interface of the window en route to the camera. These light rays create a shifted replica of the same image.

The total length of *path 2* is *greater* than the total length of *path 1*. The difference in the lengths of the paths is depicted in green color in Fig. 1. Due to the longer distance, light rays following *path 2* create a *smaller* image than light rays that following *path 1*. This effect repeats itself in the higher orders of the reverberations. The same phenomenon of different image sizes is valid for $L_{\rm t}$ as well. This is a result of perspective: if the projection was orthographic, then the changed path length would not have mattered. In our experimental setup, the difference of the paths was about 1% of the total path length. This path difference is sufficient to create a noticeable difference in the size of the replicas, up to several pixels.

Let us consider how different pixels in the original image are reverberated. Consider Fig. 2(a). A pixel in the upper part of $L_{\rm r}$ reverberates to slightly lower pixels in the acquired frame. On the other hand, in Fig. 2(b), a pixel at the bottom of $L_{\rm r}$ reverberates to higher pixels in the acquired frame. This is the result of image size reduction, caused by perspective. Thus, different pixels generally have a direction of reverberation that is slightly different than others.

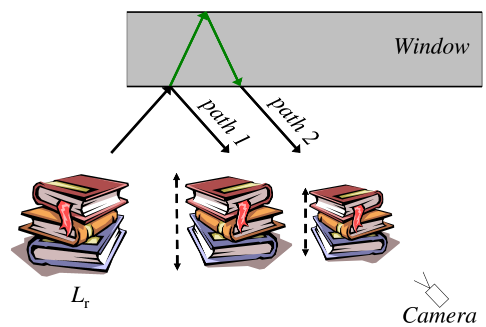

Figure 1. A light ray that creates the first image of the reverberation (denoted by *path 1*) travels a shorter way from the object $L_{\rm r}$ to the camera, than the ray that creates the second image of the reverberation (denoted by *path 2*). Thus, the second ray creates a smaller image. The difference in the paths is marked in green.

These observations yield two differences between this image formation model and the orthographic model presented in Sec. 2 of Ref. [1]. First, the perspective model has two dimensional (2D) shifts, since pixels reverberate to heights slightly different than their original one. Second, the model is *not* spatially invariant, since different pixels reverberate to different heights, in a shift that depends on the original location. Thus, a model of simple space-invariant convolution is not strictly correct, but an approximation.

2. Residual Edge Artifacts

This section shows residual edge artifacts that are created when recovery is not in full consistency with a simple orthographic approximation. In reality, the image formation