In a mixed-reality environment, virtual objects are merged into a real scene. This augmentation offers great possibilities to present content in innovative ways. The emphasis of this thesis lies on a perceptually plausible light simulation for reflective and refractive objects in a mixed-reality environment, so virtual objects should seamlessly merge with the real environment.

Mixed-Reality Environment Problem Statement

Integrate light effects from reflective and refractive objects in a mixed-reality environment.

Simulate caustics, which is a light focusing due to scattering.

Compute these complex lighting effects in real time to handle the user interaction without delay.

Apply the differential rendering effect also to reflected and refracted real surfaces.

Differential Rendering for Reflected and Refracted Surfaces

Differential rendering (DR) is the fundamental method to merge virtual objects with a real scene.

Reduces the error from the material approximation.

Computes two light solutions:
- for real objects
- for real and virtual objects and adds their difference to the masked camera image.

The problem is that the color value of the visible point p’ has no relation to the reflected point p_{refl} in the camera image.

The original DR algorithm uses only the estimated material (see the reflection of the desk in the teapot).

Re-use information from the camera image by a back-projection of p_{refl}.

Contributes to the overall impression.

Results Contributions

Extension for differential instant radiosity: integrate reflective and refractive objects.

Handles various lighting situations: for real and virtual objects and light sources.

Plausible simulation of caustics: until recently ignored in mixed-reality systems.


Implementation

Reflections, refractions and caustics were integrated into the RESHADE framework: light simulation for diffuse objects, based upon differential instant radiosity.

Our method runs entirely on the GPU and achieves interactive to real-time frame rates.

These effects were computed with three image-space methods:
- Reflective impostors, which reduce the intersection complexity.
- Refractions on the entry and the exit point of the ray.
- A fast splatting method to generate the caustic pattern.

Method

Back-project reflected point (p_{refl})

and adjust the camera image when possible.

Substitute missing geometry with an environment map.

Compose the final image as
\[ L_f = L_b + L_{env} + L_{rv} - L_r. \]

Differential rendering is also applied to reflected and refracted real objects.

A real mirror reflects a virtual sphere. The light bounces multiple times (about 10 fps*).

A virtual spotlight illuminates a real bottle. It correctly refracts the scene behind and casts a virtual caustic onto the real desk (about 9 fps*).

A virtual colored glass on a real desk. The virtual light is scattered and appears as a caustic on the real desk (about 8 fps*).

*fps are frames per second on our test platform:
CPU: AMD X2 3.1 GHz, GPU: NVIDIA GTX-260 896 MB.