GPU TECHNOLOGY CONFERENCE

NANYANG TECHNOLOGICAL UNIVERSITY

MAGIC
Multi-plAtform Game Innovation Centre

GPU-based Accelerated Spectral Caustic Rendering of Homogeneous Caustic Objects

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What is Caustics ?

Caustics

Refractor/reflector (Caustic Object)

Light source from bottom plate

Spectral Caustics

- Refraction index varies across the visible wavelength
- Typical implementation : compute three times, each for R, G, and B channels and may suffer from ‘broken’ caustics
- Correct approach : redo all caustic computation for each visible wavelength

Related Work

- Various rainbow-like effect, such as Light intereference on a thin layer (Sun et al. 1999) and Diffraction (Imura et al. 2003)
- Spectral information compression, such as a set of linear basis functions (Marimont and Wandell 1992)
- Photon mapping with spectral rendering, i.e. store the photons in RGB representation (hence conversion spectral <-> RGB representations is necessity) : Lai and Christensen 2007, Hachisuka 2007

Our Work (1/2)

- Accelerate the full spectrum caustic computation while maintaining the quality
- Render using Stochastic Progressive Photon Mapping
- Two-step acceleration scheme :
  - Cluster the wavelength based on refraction similarity : to reduce the number of intersection tests
  - Determine the number of iterations based on our defined importance level

Our Work (2/2)

- Combine both steps
  - Refine each cluster (from 1st acceleration scheme) with the amount of refinement computed from the 2nd acceleration scheme
- Is implemented using OptiX, a CUDA- based ray-tracer engine
- The work has been published at :

  http://link.springer.com/article/10.1007/s00371-014-1037-z →

Acceleration Scheme 1

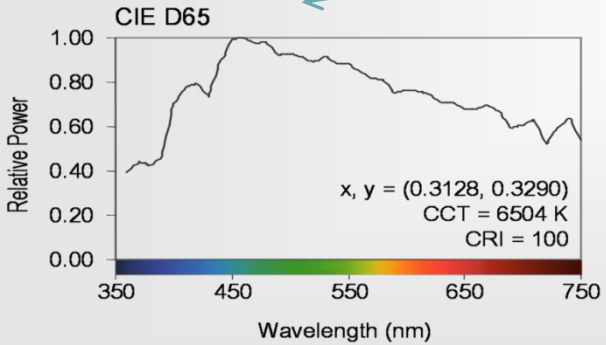
- Basic idea : If the index of refraction for a range of wavelength is almost similar, then the rays of those wavelength will be refracted to almost the same direction. Hence, cluster the rays in this range of wavelength into a ray
- To reduce the number of intersection tests
- Cluster based on the change of the refraction angle with respect to the change of wavelength

Acceleration Scheme 2 (1/2)

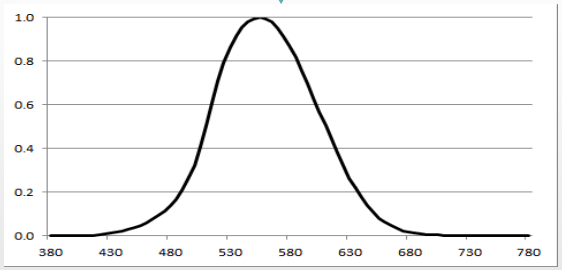
- Each wavelength should be refined with different amount depending on its importance level :

$$u(\lambda) = l(\lambda)y(\lambda)\sum_i m_i(\lambda)L_i\hat{g}_i$$

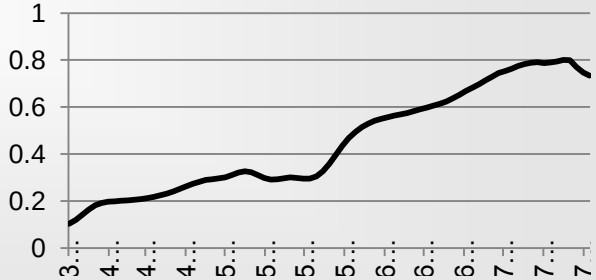
Lightness



Light Power



Luminosity Function



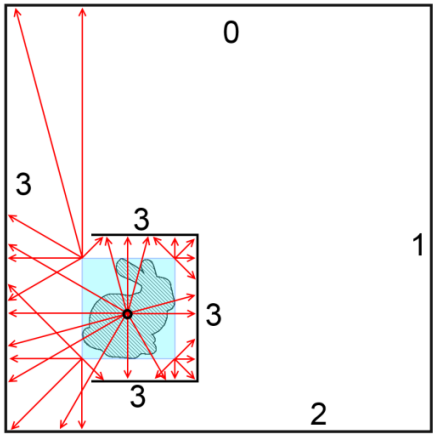
Surface Reflectance

Acceleration Scheme 2 (2/2)

- We also take into account the geometrical distribution of the surface material :

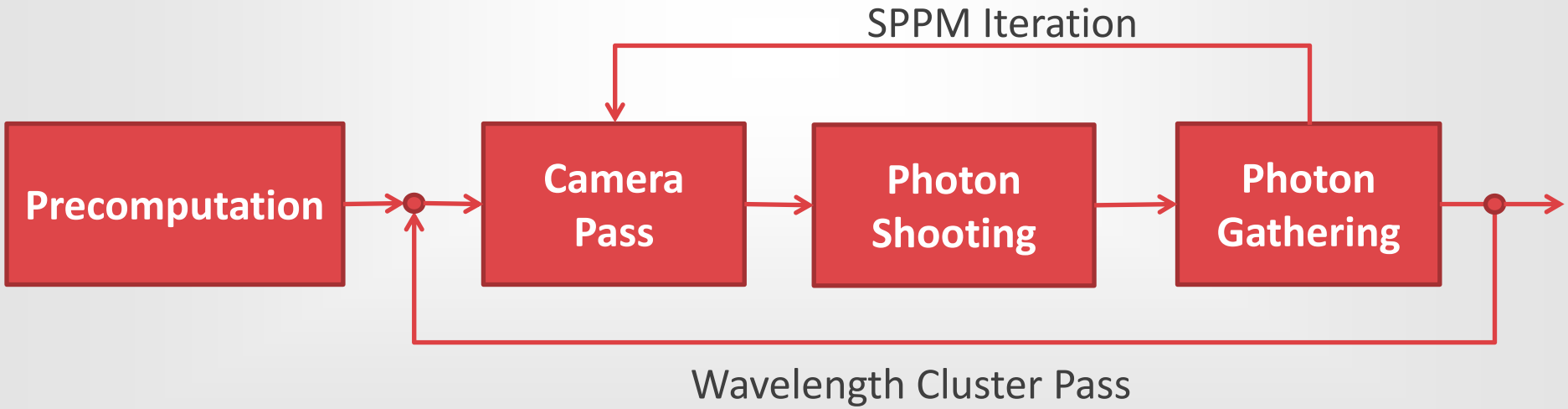
$$u(\lambda) = l(\lambda)y(\lambda)\sum_i m_i(\lambda)L_i\hat{g}_i$$

- Materials whose surfaces received more caustics should be given more weight/priority
- Use spherical uniform sampling



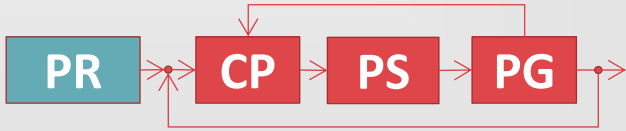
We sample the material types of the surrounding surfaces from the bounding box (blue box) corners and the center of the caustic object. The numbers denote the material type. As shown in the figure, sampling of material #3 is higher as the smaller box enclosing the caustic object has material #3. Some parts of material #0 and #2 are sampled, and none of material #1 is sampled.

GPU Implementation



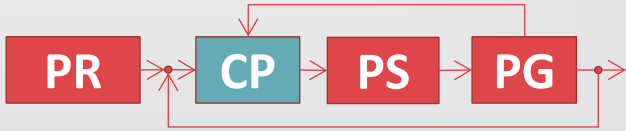
Precomputation

- Done in CPU
- All the necessary startup process
  - Compute the clustering
  - Compute the amount of iteration for each cluster



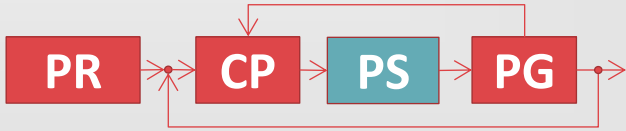
Camera Pass

- To compute direct illumination and visible points
- Output the accumulated direct lighting : light power * reflectance * eye response function for the wavelengths in the current cluster pass
- Also output geometrical information : intersection point coordinate and normal



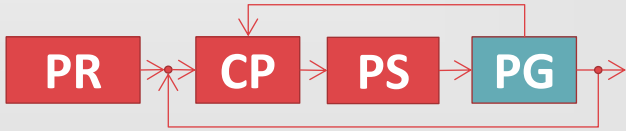
Photon Shooting Pass

- First pass of indirect illumination computation
- Each photon carries power of the wavelengths in the current cluster pass
- Power of each photon is stored in a ‘flattened’ 2D buffer (to 1D)
  - Row = one photon
  - Column = one wavelength



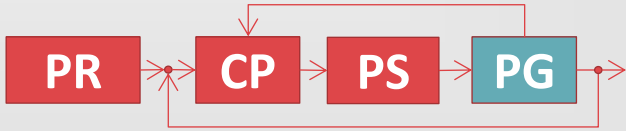
Photon Gathering Pass (1/2)

- Second pass of indirect illumination computation
- A temporary flux buffer to store gathered photon flux
  - For each gathered photon, accumulate their flux (multiplied by surface reflectance) for each wavelength in the current cluster pass
  - Row = One visible pixel
  - Column = One wavelength



Photon Gathering Pass (2/2)

- Update the shared accumulated flux (based on the temporary flux of current iteration and shared accumulated flux) for each wavelength in the current cluster pass
- To visualize, multiply and accumulate the shared accumulated flux with eyes response function for each wavelength and combine with the direct illumination result

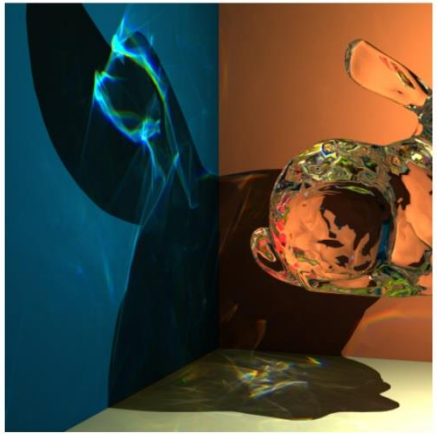


Experiments

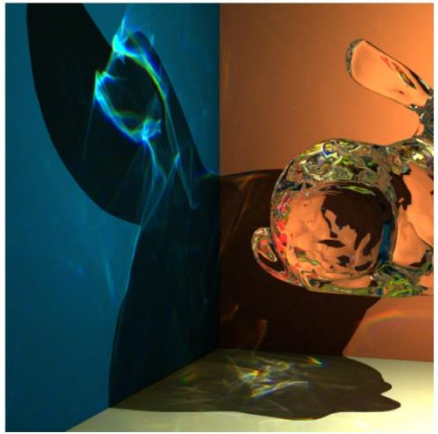
- CPU Intel I7-3820 3.60 GHz and GPU : GTX 690 4 GB
- Was implemented in OptiX
  - GPU-based ray tracing engine, was built over CUDA
- Maximum iterations for each nm : 2000
- Minimum nm step : 1 nm
- Threshold : 0.1 degree

Results (1/4)

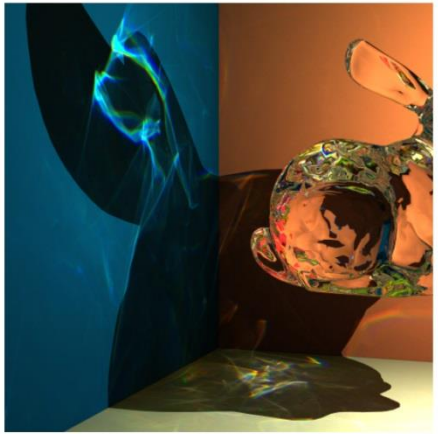
Brute Force | Ours | Radziszewski et al.



(a) 38.62 hours, 802000 iterations

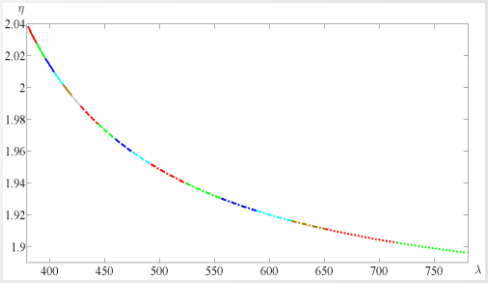


(b) 0.28 hours (speed up 137.93 times), 5088 iterations



(c) 2.31 hours (speed up 16.72 times), 47341 iterations

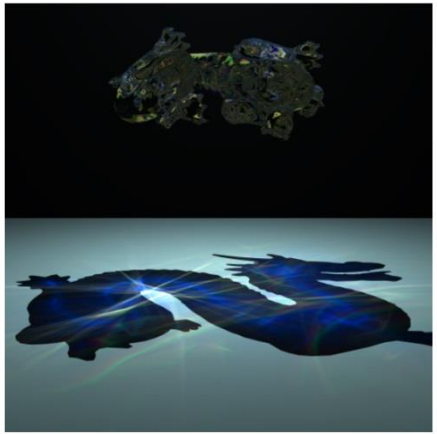
IOR



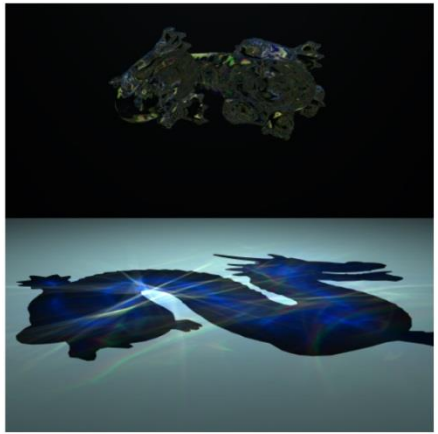
Natural, N-SF66

Results (2/4)

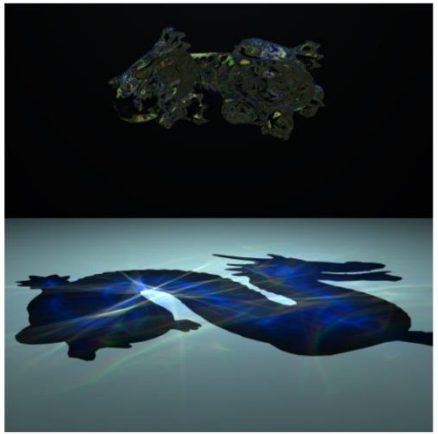
Brute Force | Ours | Radziszewski et al. | IOR



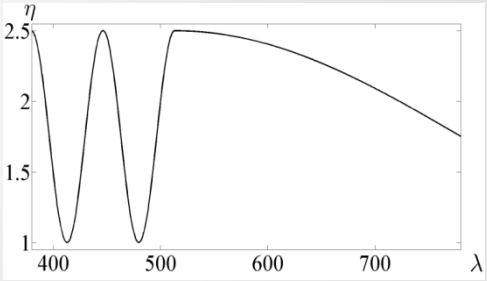
(d) 37.95 hours, 802000 iterations



(e) 2.99 hours (speed up 12.69 times), 60301 iterations



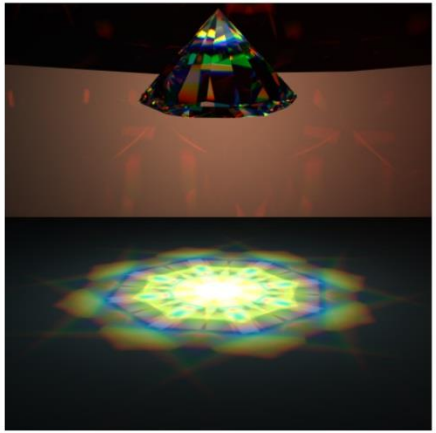
(f) 11.10 hours (speed up 3.42 times), 233106 iterations



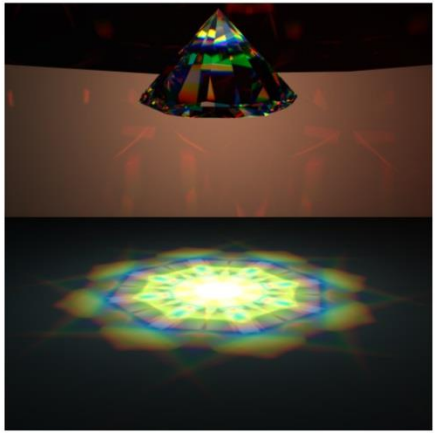
Artificial

Results (3/4)

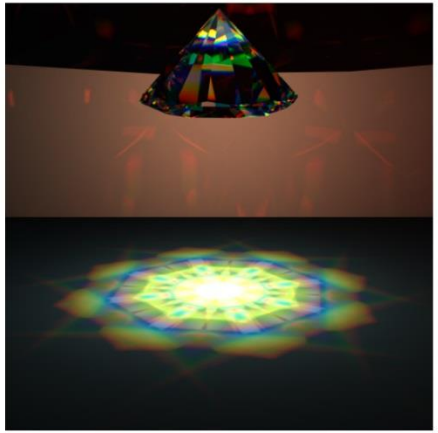
Brute Force | Ours | Radziszewski et al. | IOR



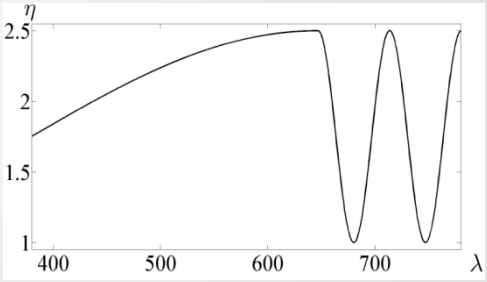
(g) 33.57 hours, 802000 iterations



(h) 3.46 hours (speed up 9.70 times), 78714 iterations



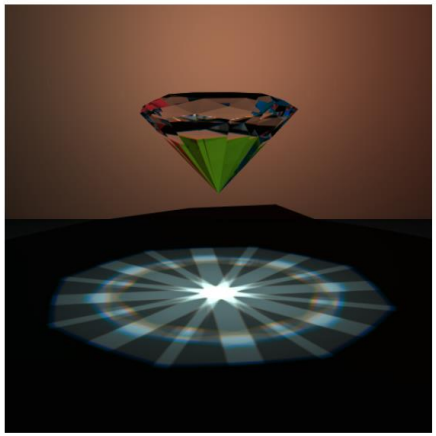
(i) 9.90 hours (speed up 3.39 times), 231239 iterations



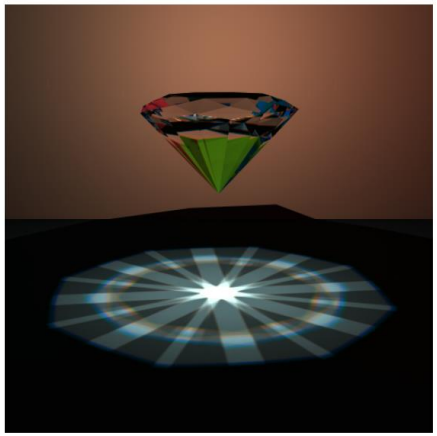
Artificial

Results (4/4)

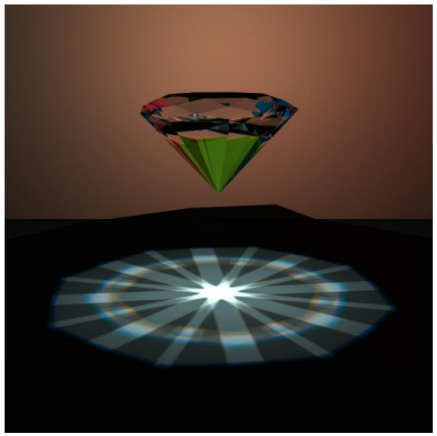
Brute Force | Ours | Radziszewski et al. | IOR



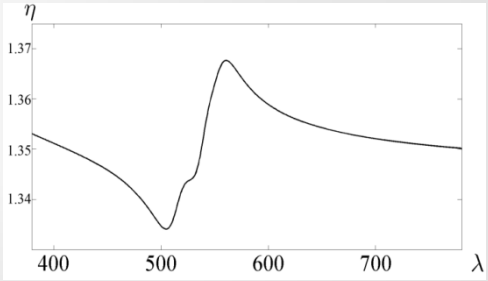
(j) 33.96 hours, 802000 iterations



(k) 1.94 hours (speed up 17.51 times), 37699 iterations



(l) 2.12 hours (speed up 16.02 times), 41572 iterations



Natural,
Rose Bengal 10%
Solution

Application

- Caustic object design and visualization
- Design the caustic object (e.g. a gemstone, crystal vase, glass bracelet, etc.) and use our method to render it to observe the refraction and caustic effects
- The rendering can be implemented in a renderfarm system, similar to our GPU renderfarm system presented in GTC 2014 (Season S4356)

Conclusion (1/2)

- Main strength of our method :
  - Quality of our rendering result is close to Brute Force rendering result
  - Also, we achieve rendering speed acceleration with the acceleration magnitude from tens to thousands
  - Compared to Radziszewski et al.'s, we also achieve higher acceleration

Conclusion (2/2)

- Limitations :
  - Consider only single type of caustic object IOR
  - Not optimized for dynamic scene

Future Work

- Handle scene that has multiple caustic objects, each with different index of refraction
- Sample the surrounding caustic objects by using real-time approximate caustic renderer
- Apply our acceleration scheme to other rendering algorithms

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Discussion

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