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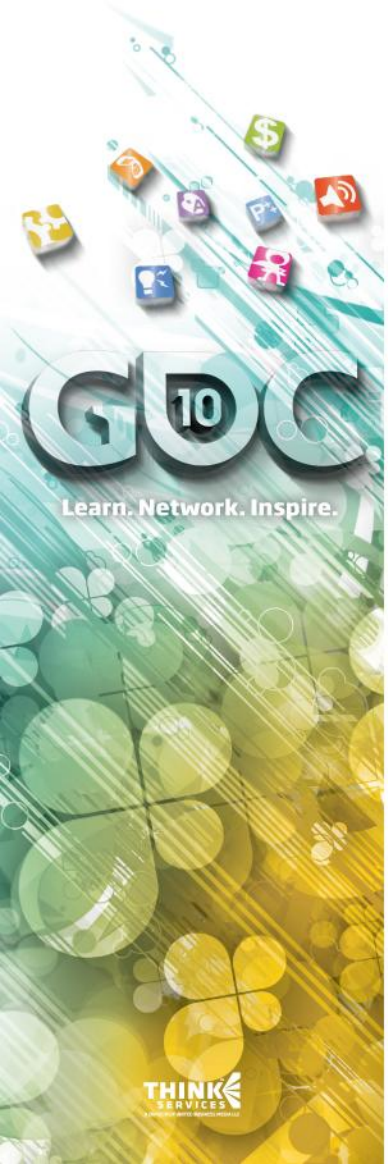
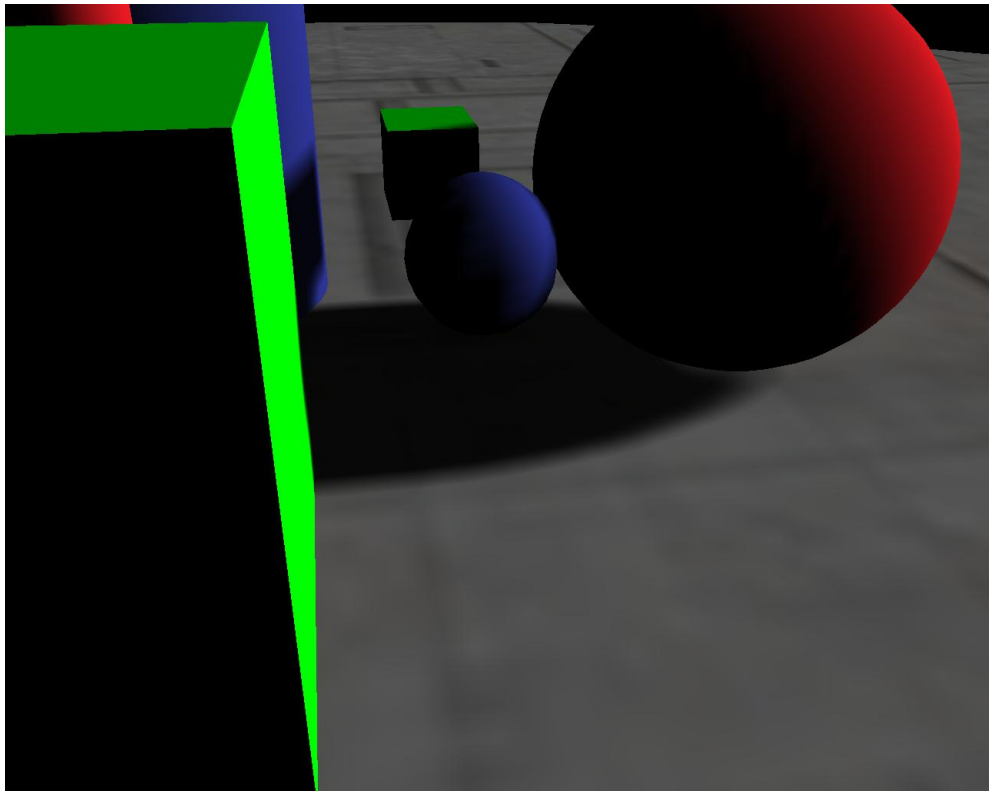


Direct3D 11 Indirect Illumination

Holger Gruen
European ISV Relations AMD



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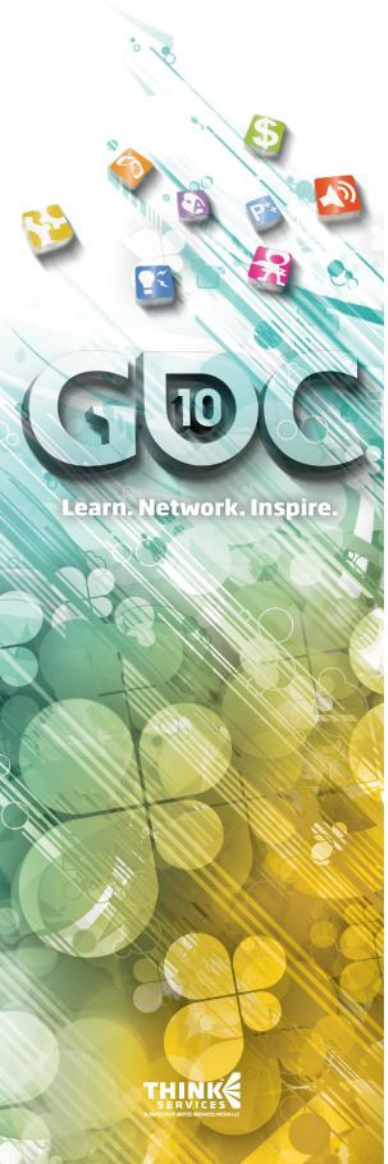

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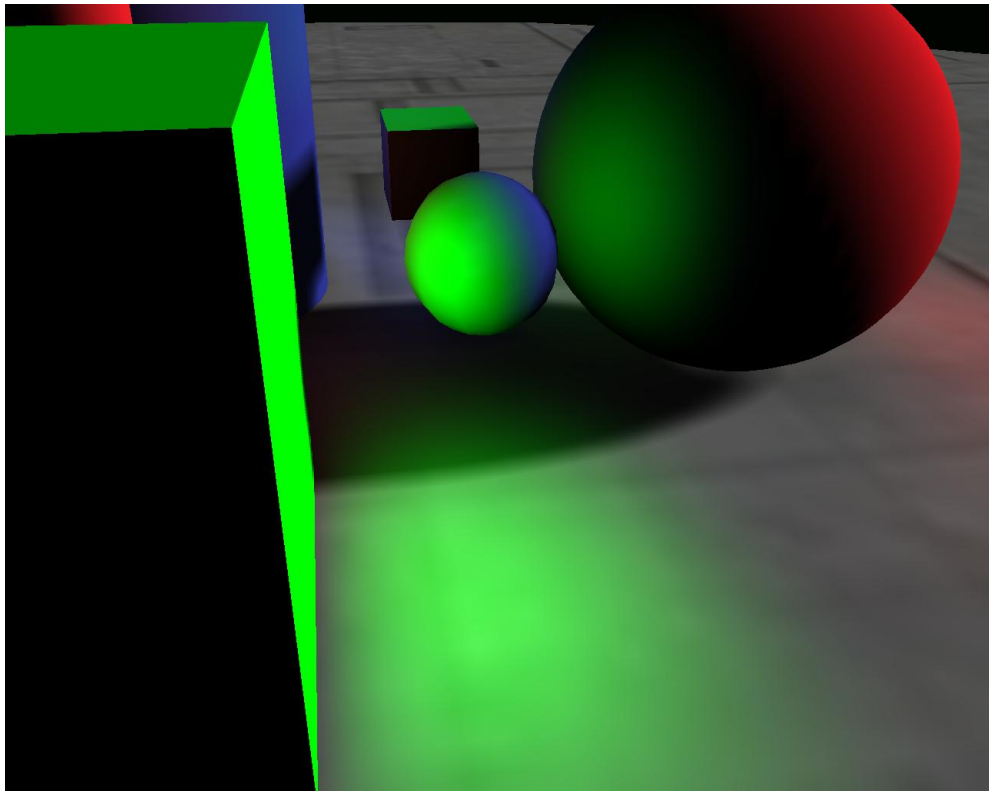

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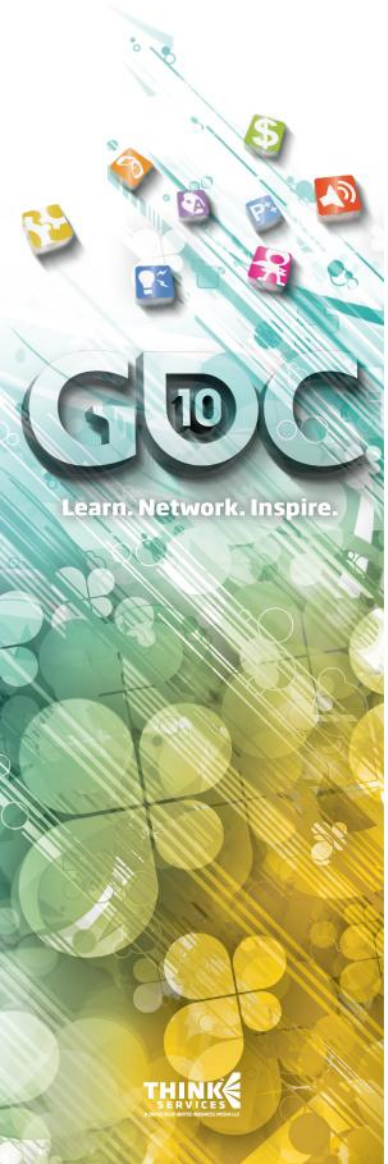

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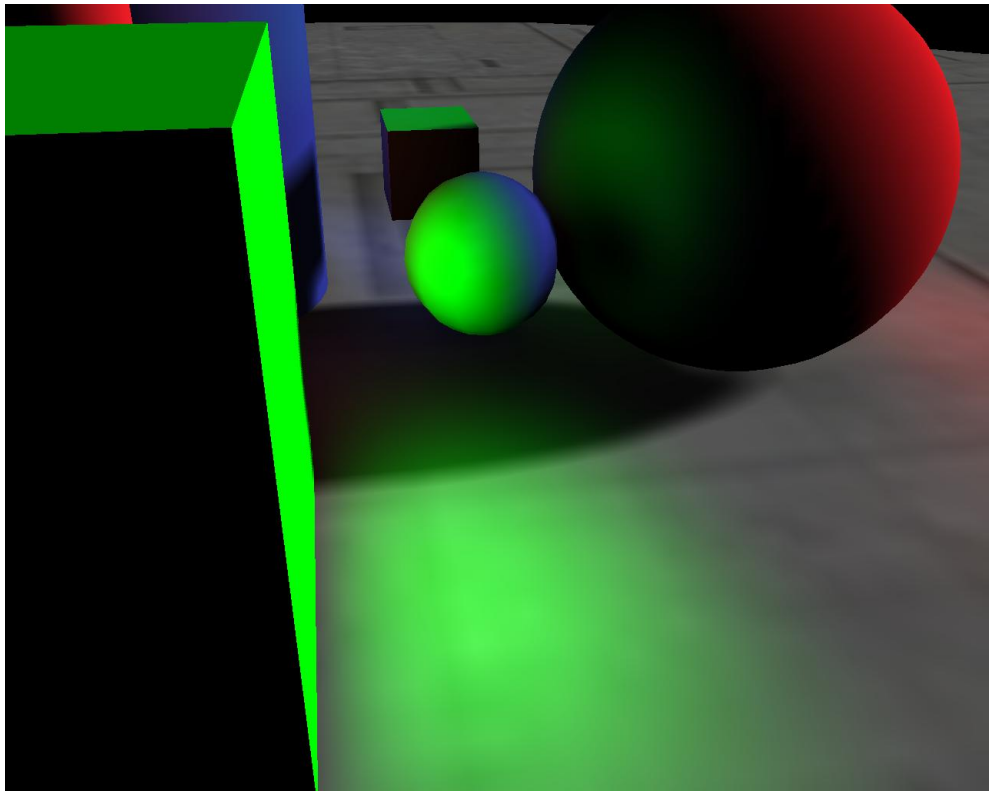
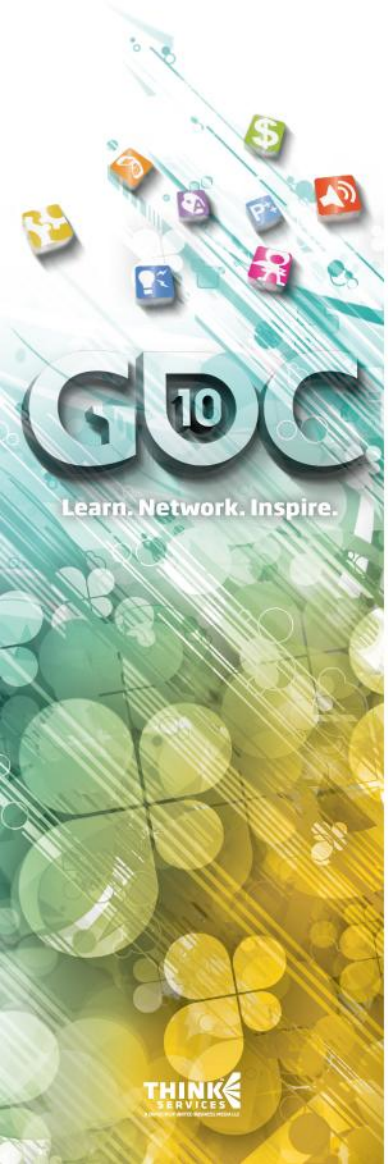


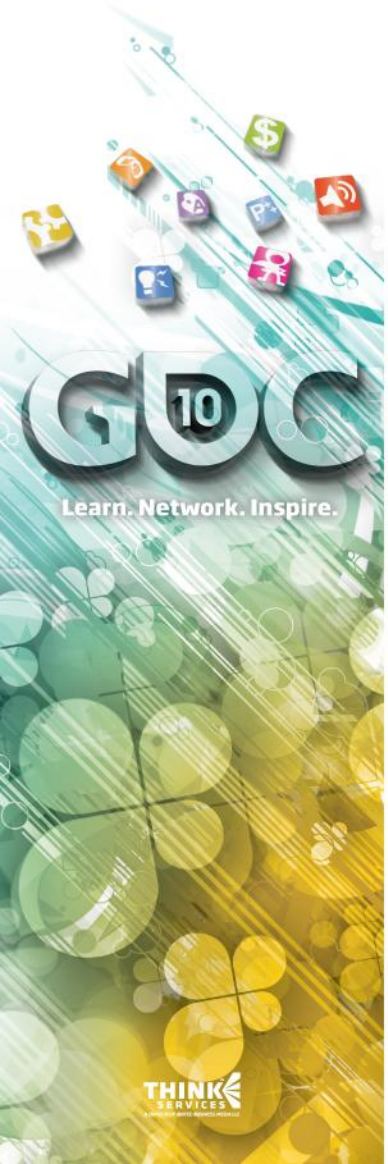


Indirect Illumination Introduction 1

- Real-time Indirect illumination is an active research topic
- Numerous approaches exist

  Reflective Shadow Maps (RSM) [Dachsbacher/Stammiger05]
  Splatting Indirect Illumination [Dachsbacher/Stammiger2006]
  Multi-Res Splatting of Illumination [Wyman2009]
  Light propagation volumes [Kapalanyan2009]
  Approximating Dynamic Global Illumination in Image Space [Ritschel2009]
- Only a few support indirect shadows

  Imperfect Shadow Maps [Ritschel/Grosch2008]
  Micro-Rendering for Scalable, Parallel Final Gathering(SSDO) [Ritschel2010]
  Cascaded light propagation volumes for real-time indirect illumination [Kapalanyan/Dachsbacher2010]
- Most approaches somehow extend to multi-bounce lighting



Indirect Illumination Introduction 2

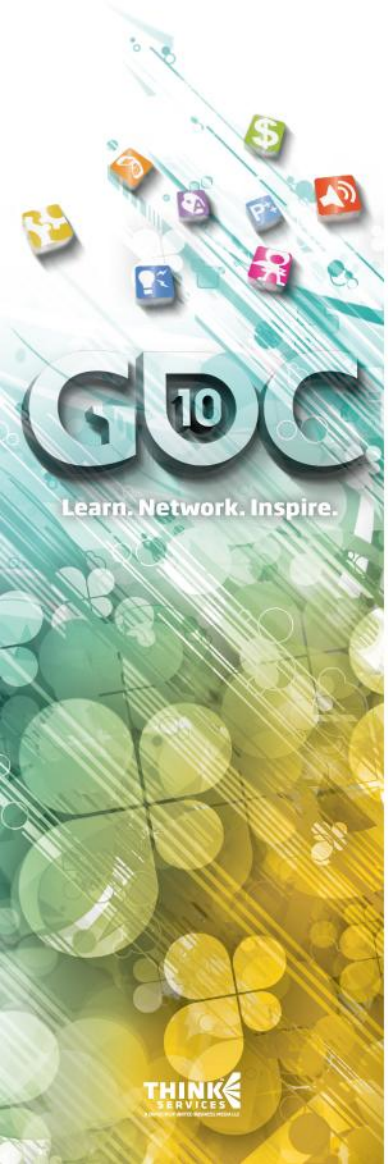
- This section will cover

  An efficient and simple DX9-compliant RSM based implementation for smooth one bounce indirect illumination

  - Indirect shadows are ignored here

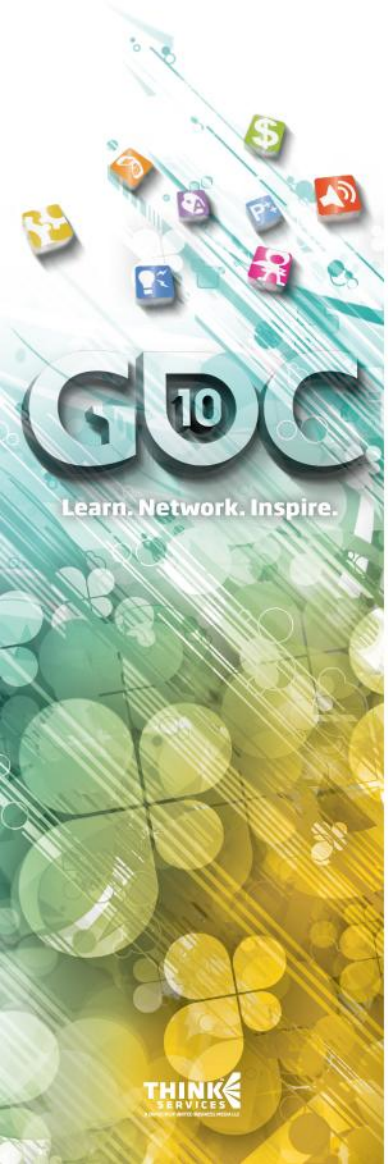
- A Direct3D 11 technique that traces rays to compute indirect shadows

  - Part of this technique could generally be used for ray-tracing dynamic scenes

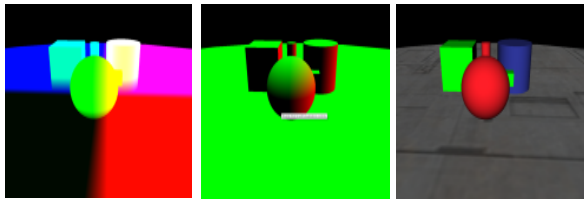


Indirect Illumination w/o Indirect Shadows

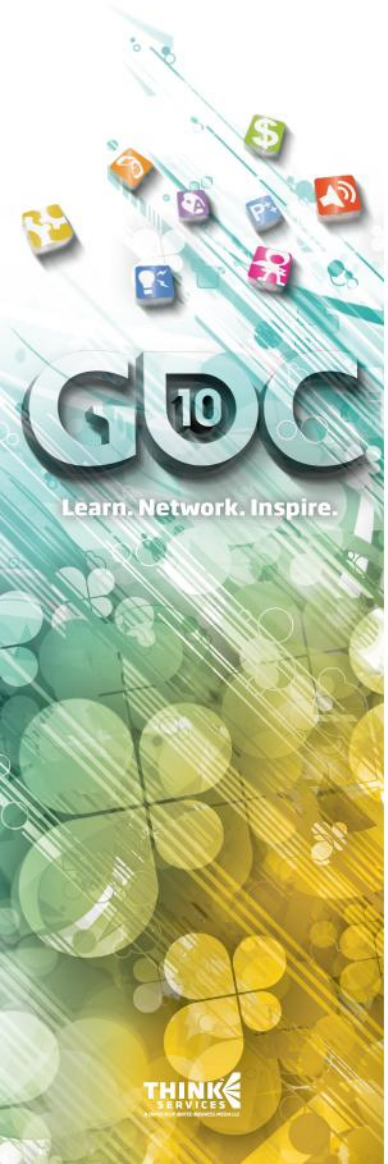
1. Draw scene g-buffer
2. Draw Reflective Shadowmap (RSM)
   - RSM shows the part of the scene that recieves direct light from the light source
3. Draw Indirect Light buffer at ½ res
   - RSM texels are used as light sources on g-buffer pixels for indirect lighting
4. Upsample Indirect Light (IL)
5. Draw final image adding IL



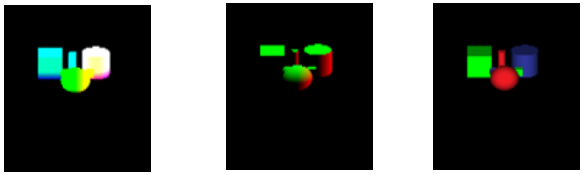
Step 1



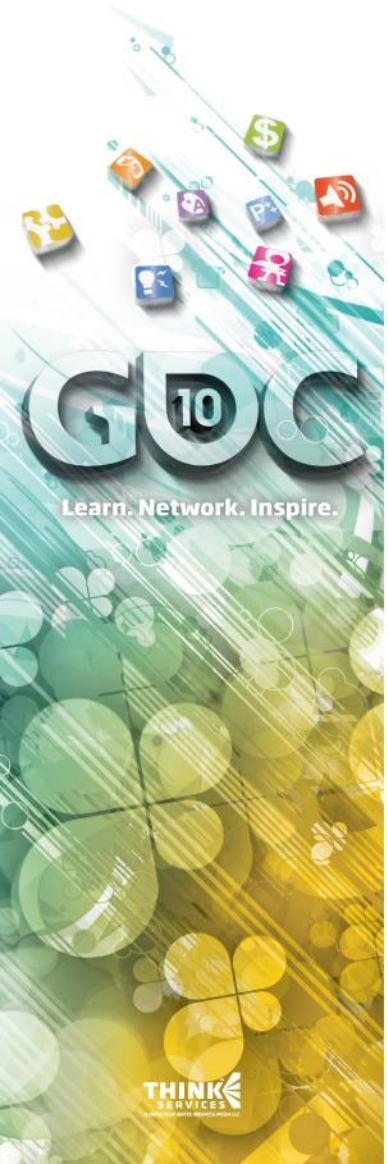
- G-Buffer needs to allow reconstruction of
  - World/Camera space position
  - World/Camera space normal
  - Color/ Albedo
- DXGI_FORMAT_R32G32B32A32_FLOAT positions may be required for precise ray queries for indirect shadows



Step 2



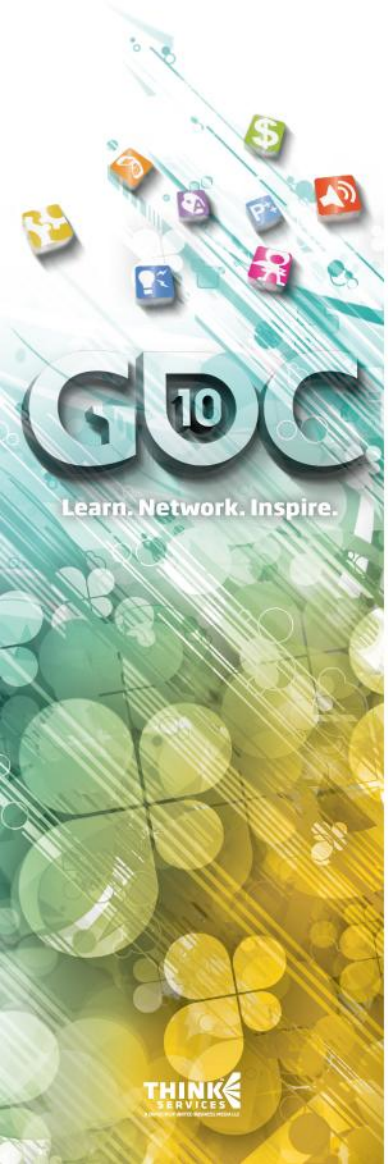
- RSM needs to allow reconstruction of
  - World/Camera space position
  - World/Camera space normal
  - Color/ Albedo
- Only draw emitters of indirect light
- DXGI_FORMAT_R32G32B32A32_FLOAT position may be required for ray precise queries for indirect shadows

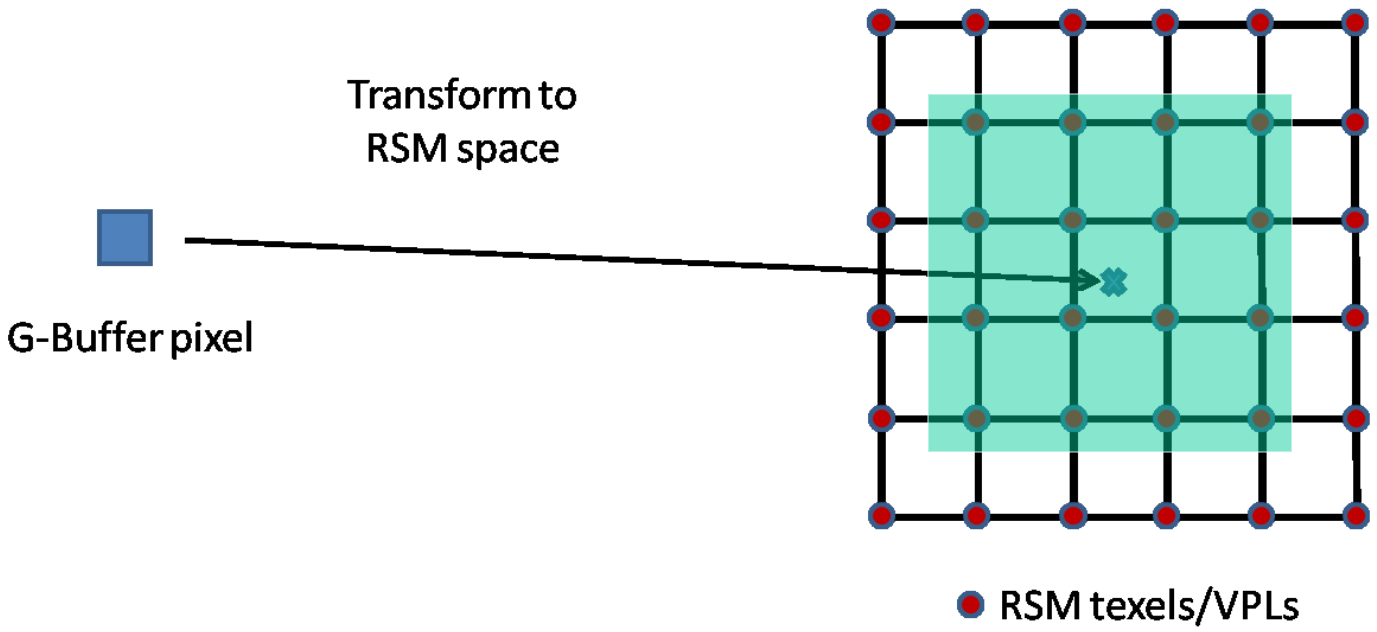


Step 3

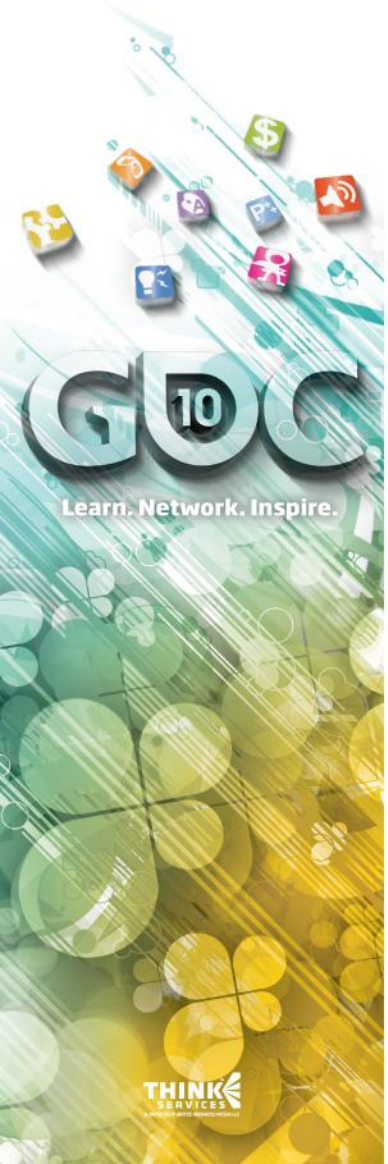
- Render a ½ res IL as a deferred op
- Transform g-buffer pix to RSM space
  - ->Light Space->project to RSM texel space
- Use a kernel of RSM texels as light sources
  - RSM texels also called Virtual Point Light(VPL)
- Kernel size depends on
  - Desired speed
  - Desired look of the effect
  - RSM resolution

Computing IL at a G-buf Pixel 1

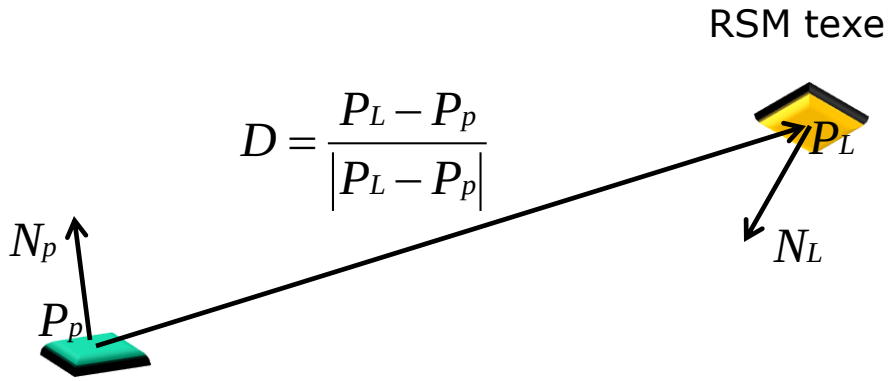




Sum up contribution of all VPLs in the kernel



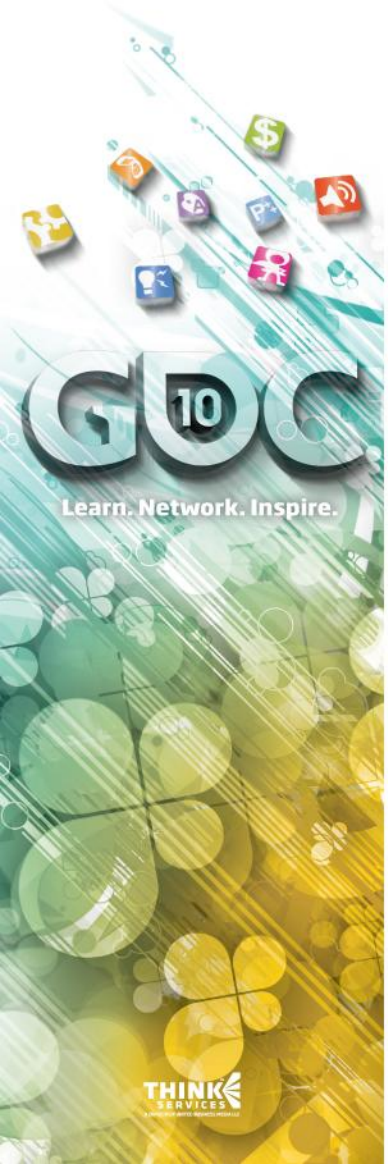
Computing IL at a G-buf Pixel 2



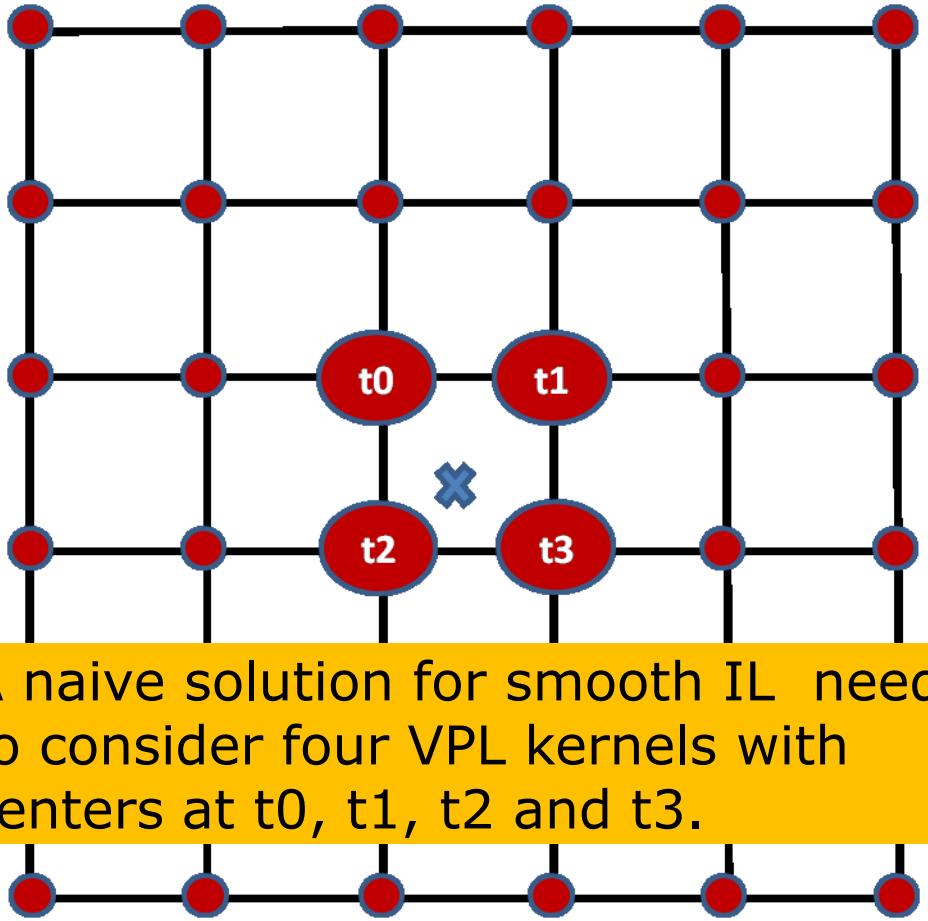
g-buffer pixel

$$Contribution_{VPL} = \frac{sat(N_P \cdot D) \cdot sat(N_L \cdot (-D))}{|P_L - P_p|^2} \cdot Col_{VPL} \cdot Area_{VPL}$$

This term is very similar to terms used in radiosity form factor computations

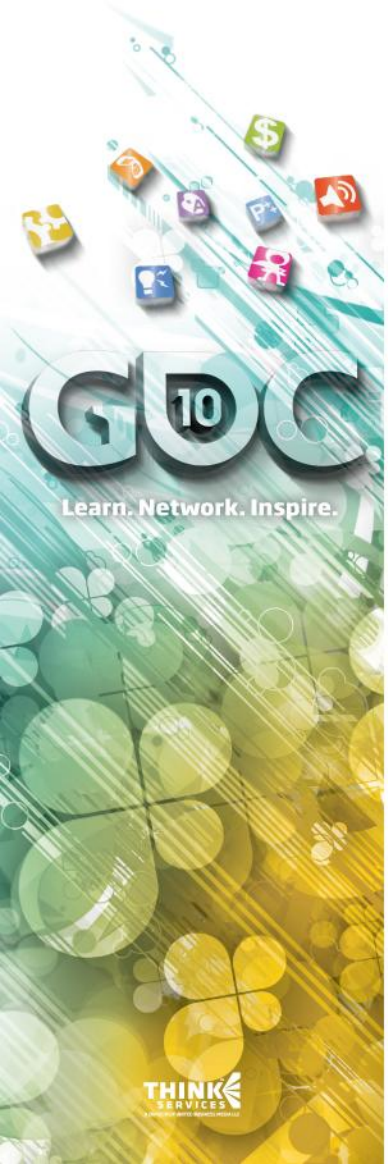


Computing IL at a G-buf Pixel 3

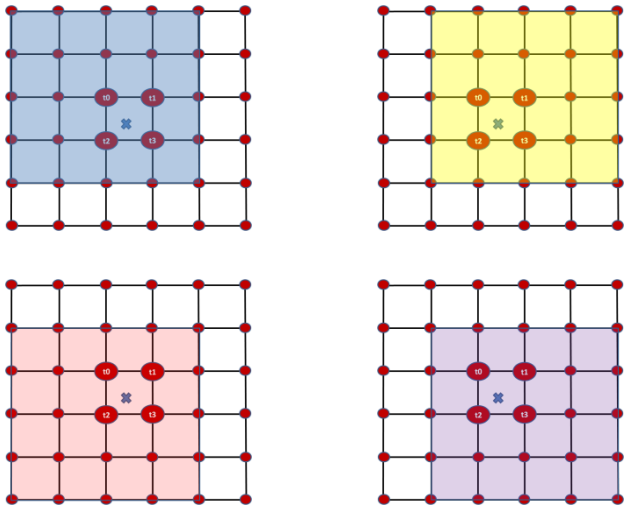


A naive solution for smooth IL needs to consider four VPL kernels with centers at t0, t1, t2 and t3.

stx : sub RSM texel x position [0.0, 1.0[
sty : sub RSM texel y position [0.0, 1.0[



Computing IL at a g-buf pixel 4

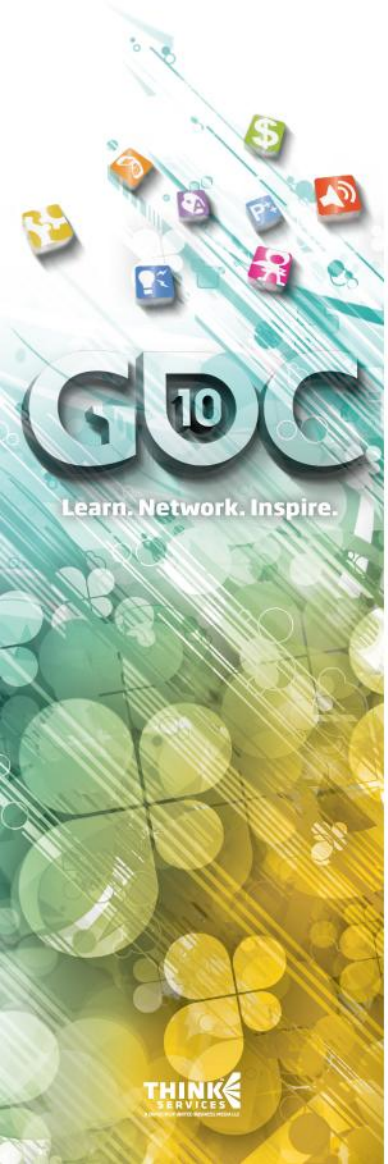


IndirectLight = (1.0f-sty) * ((1.0f-stx) * ■ + stx * ■) +
(0.0f+sty) * ((1.0f-stx) * ■ + stx * ■)

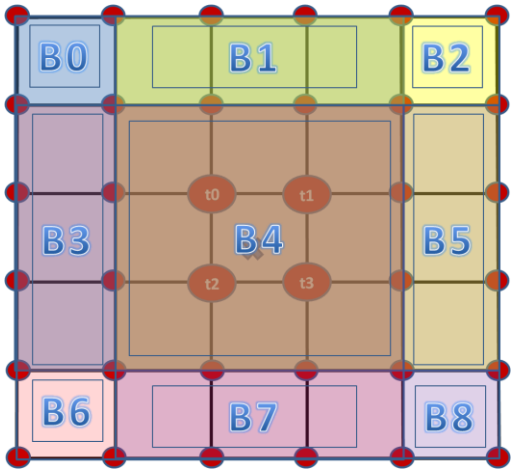
Evaluation of 4 big VPL kernels is slow ☹

stx : sub texel x position [0.0, 1.0[
sty : sub texel y position [0.0, 1.0[

■ VPL kernel at **t0**
■ VPL kernel at **t2**
■ VPL kernel at **t1**
■ VPL kernel at **t3**



Computing IL at a g-buf pixel 5



SmoothIndirectLight =

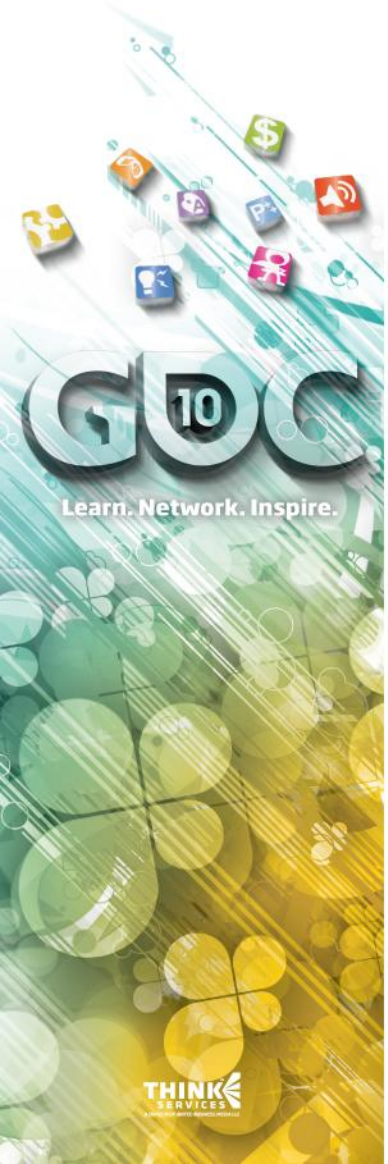
(1.0f-sty)*(((1.0f-stx)*(B0+B3)+stx*(B2+B5))+B1)+

(0.0f+sty)*(((1.0f-stx)*(B6+B3)+stx*(B8+B5))+B7)+B4

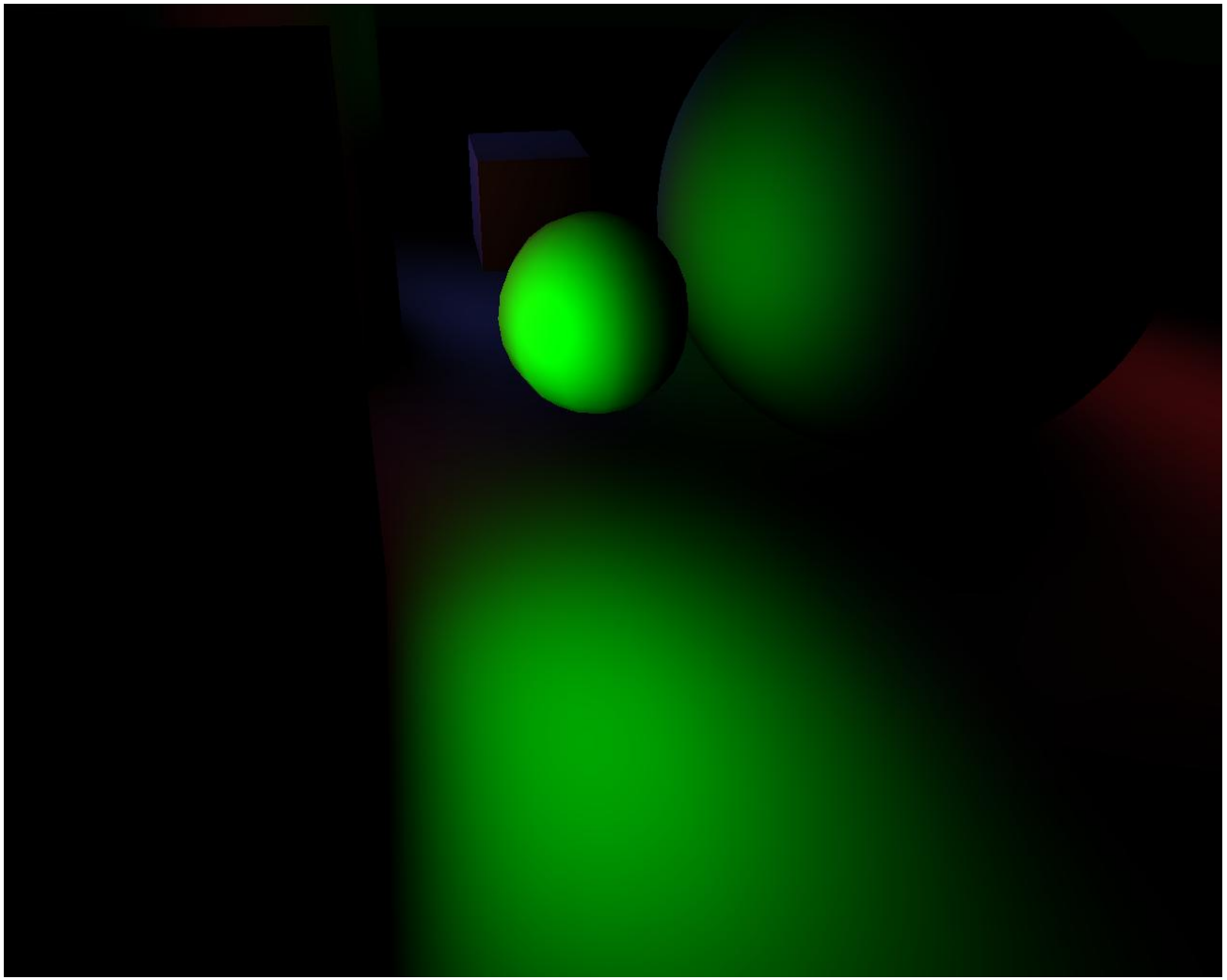
stx : sub RSM texel x position of g-buf pix [0.0, 1.0[

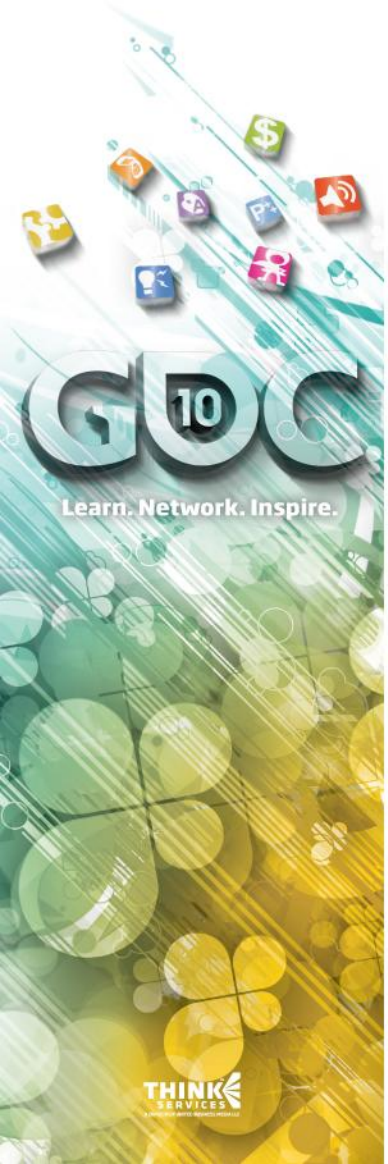
sty : sub RSM texel y position of g-buf pix [0.0, 1.0[

This trick is probably known to some of you already. See backup for a detailed explanation !



Indirect Light Buffer

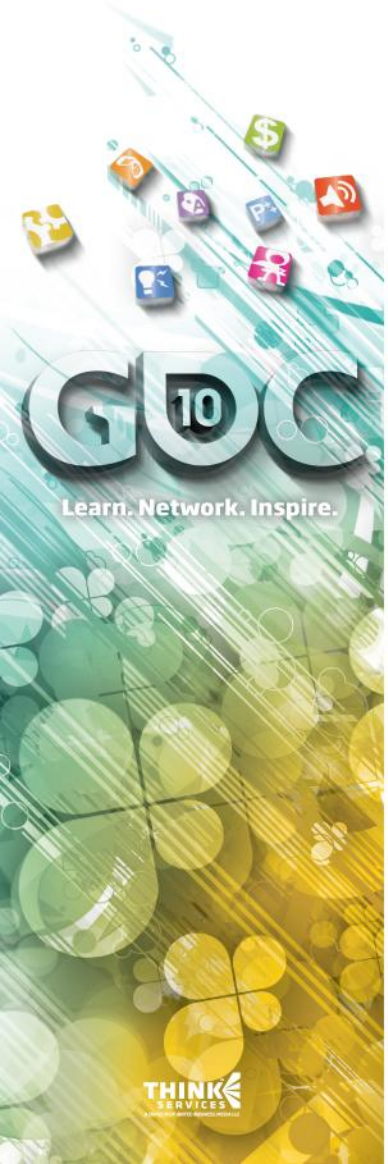




Step 4

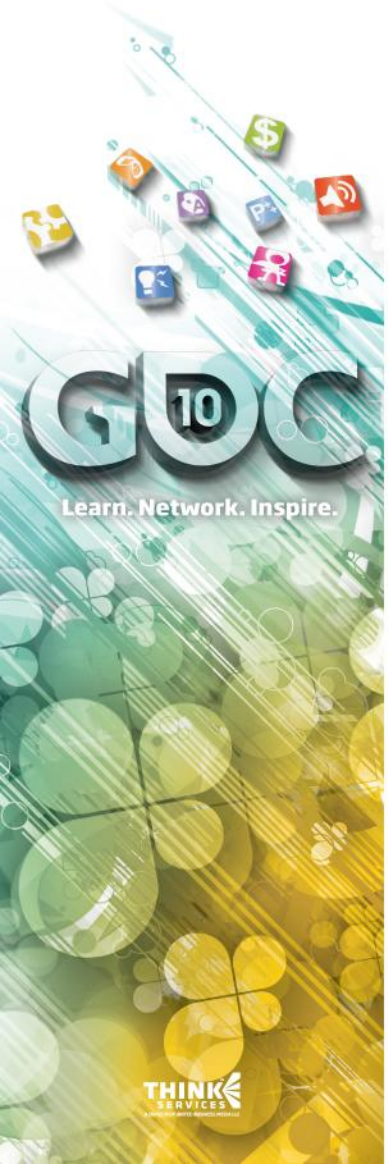
- Indirect Light buffer is ½ res
- Perform a bilateral upsampling step

  See Peter-Pike Sloan, Naga K. Govindaraju, Derek Nowrouzezahrai, John Snyder. "Image-Based Proxy Accumulation for Real-Time Soft Global Illumination". Pacific Graphics 2007
- Result is a full resolution IL

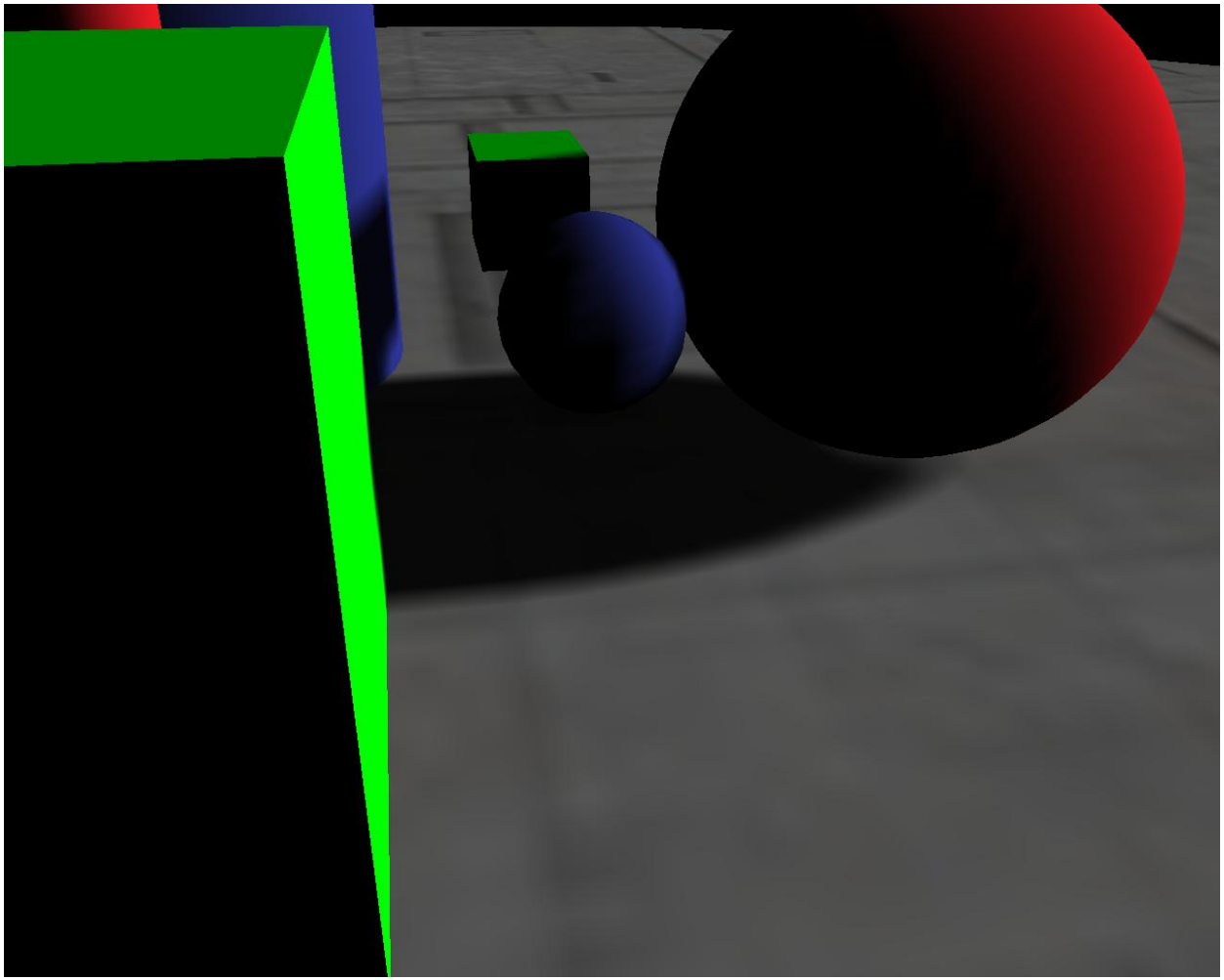


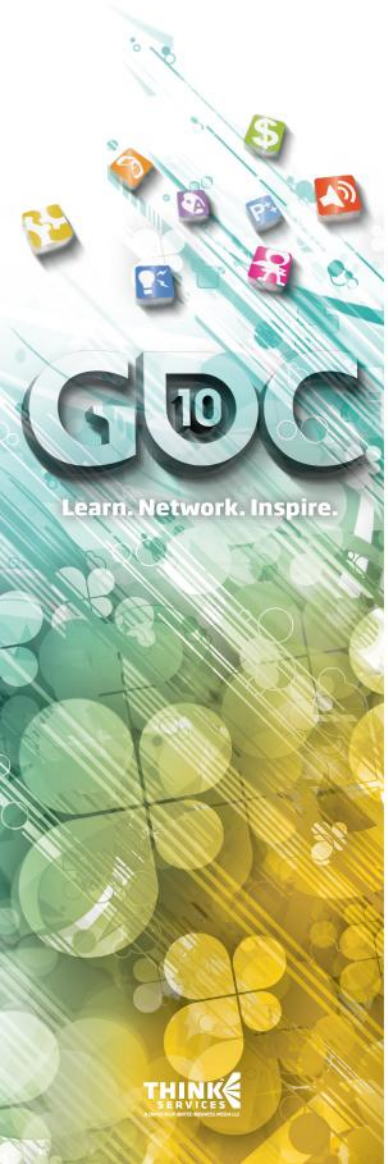
Step 5

- Combine
  - Direct Illumination
  - Indirect Illumination
  - Shadows (not mentioned)

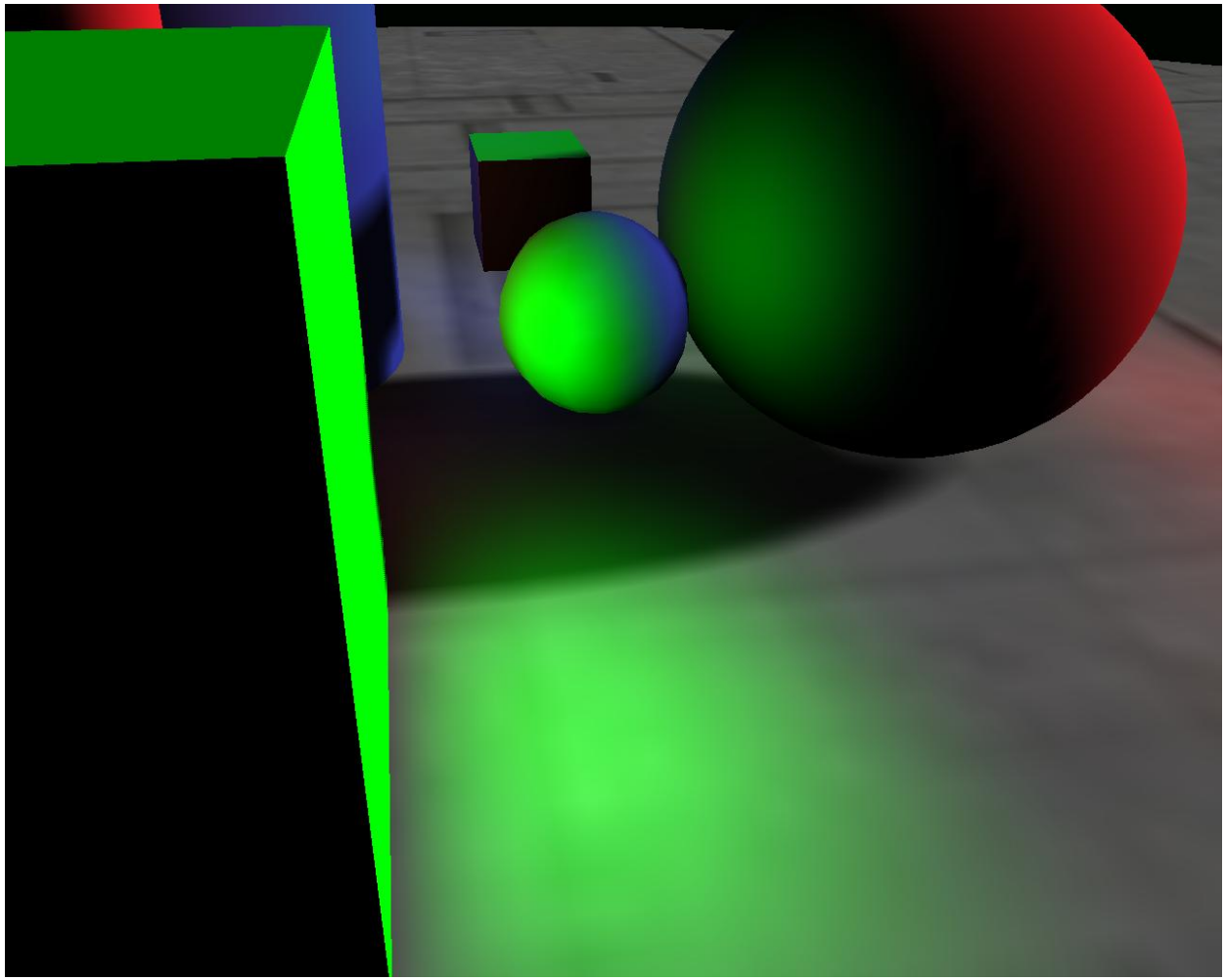


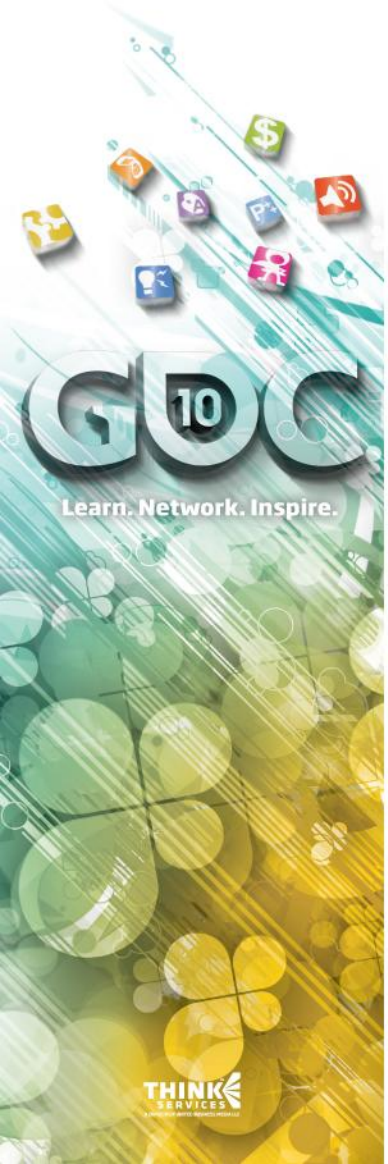
Scene without IL



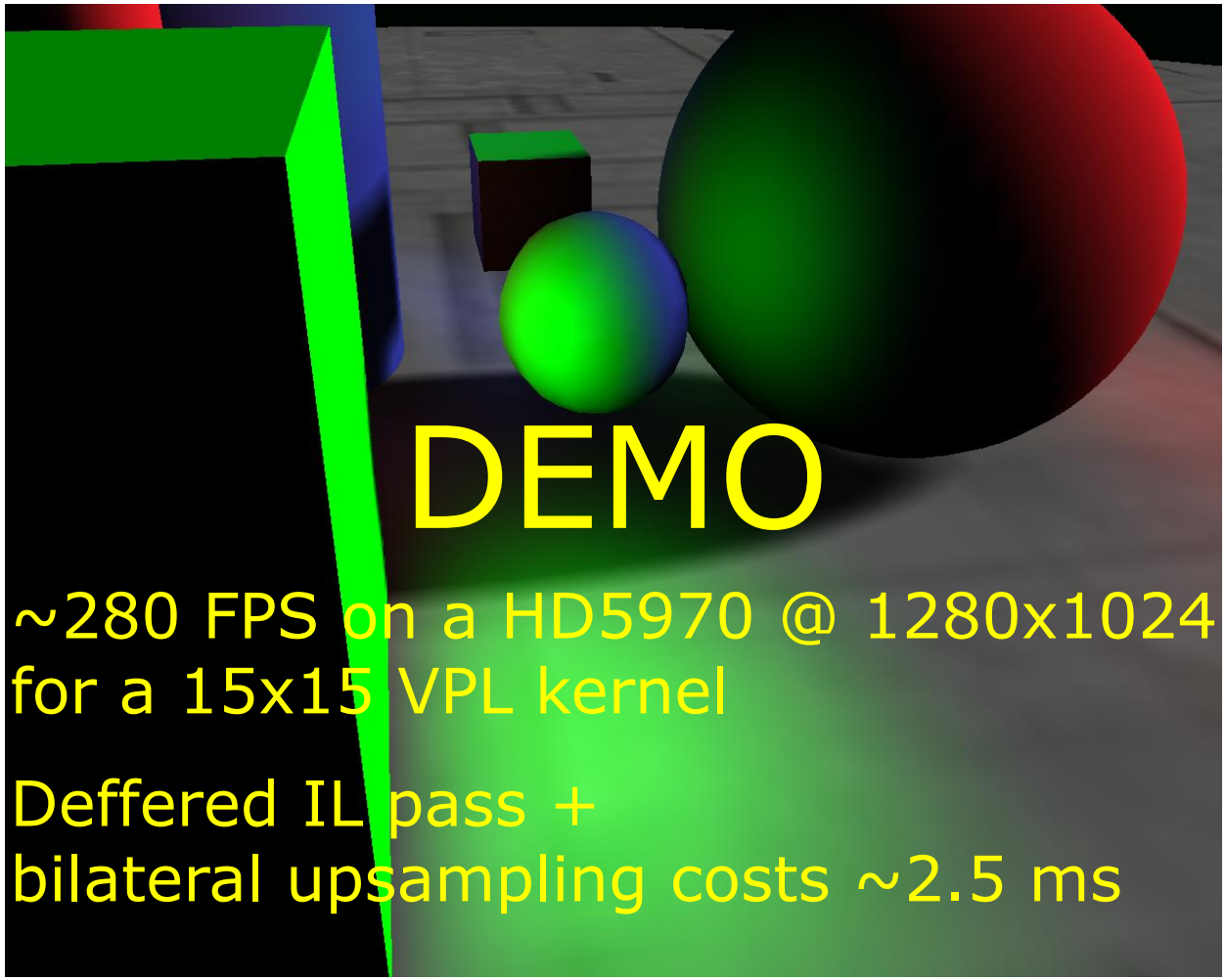


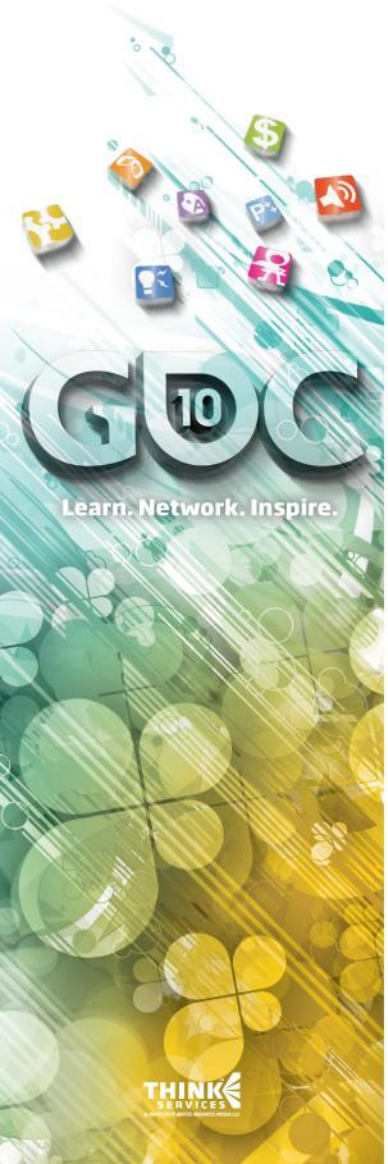
Combined Image





Combined Image





How to add Indirect Shadows

1. Use a CS and the linked lists technique
   - Insert blocker geomety of IL into 3D grid of lists – let‘s use the triangles of the blocker for now
     - see backup for alternative data structure
2. Look at a kernel of VPLs again
3. Only accumulate light of VPLs that are occluded by blocker tris
   - Trace rays through 3d grid to detect occluded VPLs
   - Render low res buffer only
4. Subtract blocked indirect light from IL buffer
   - Blurred version of low res blocked IL is used
     - Blur is combined bilateral blurring/upsampling

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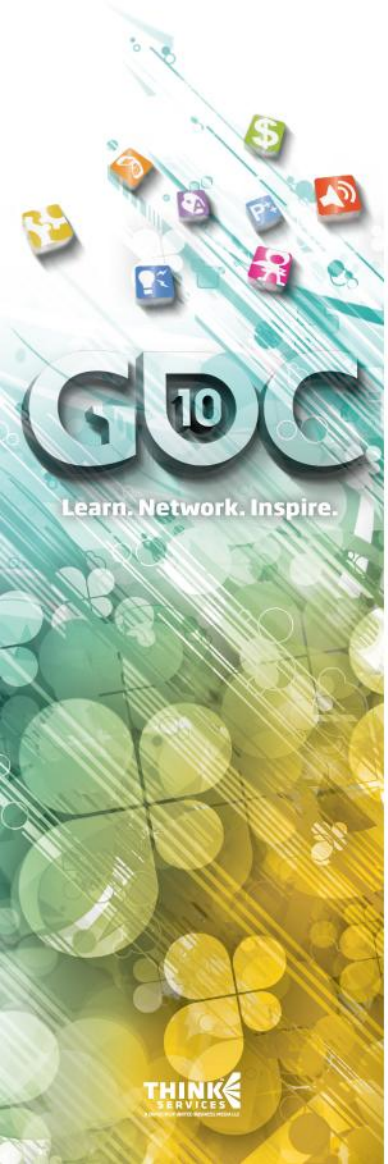
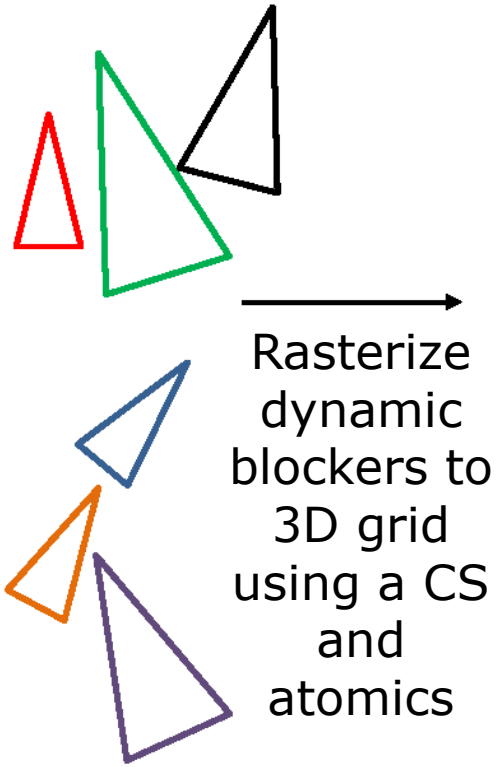


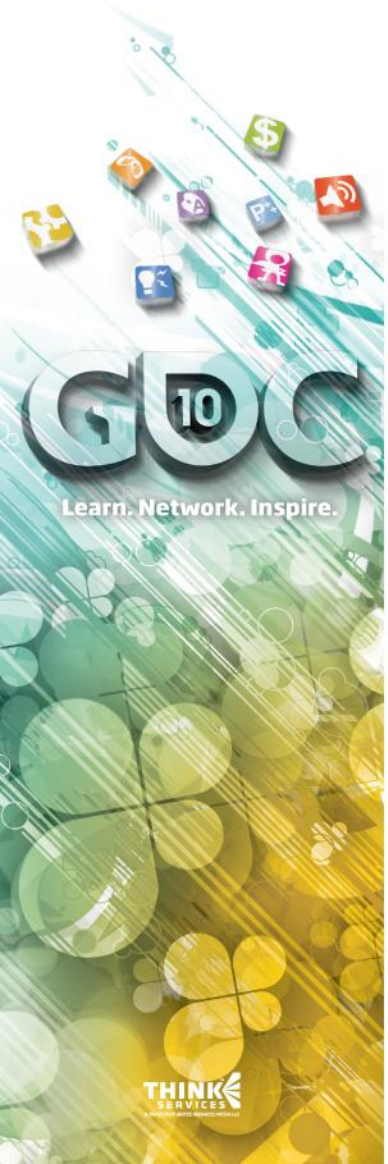
Insert tris into 3D grid of triangle lists

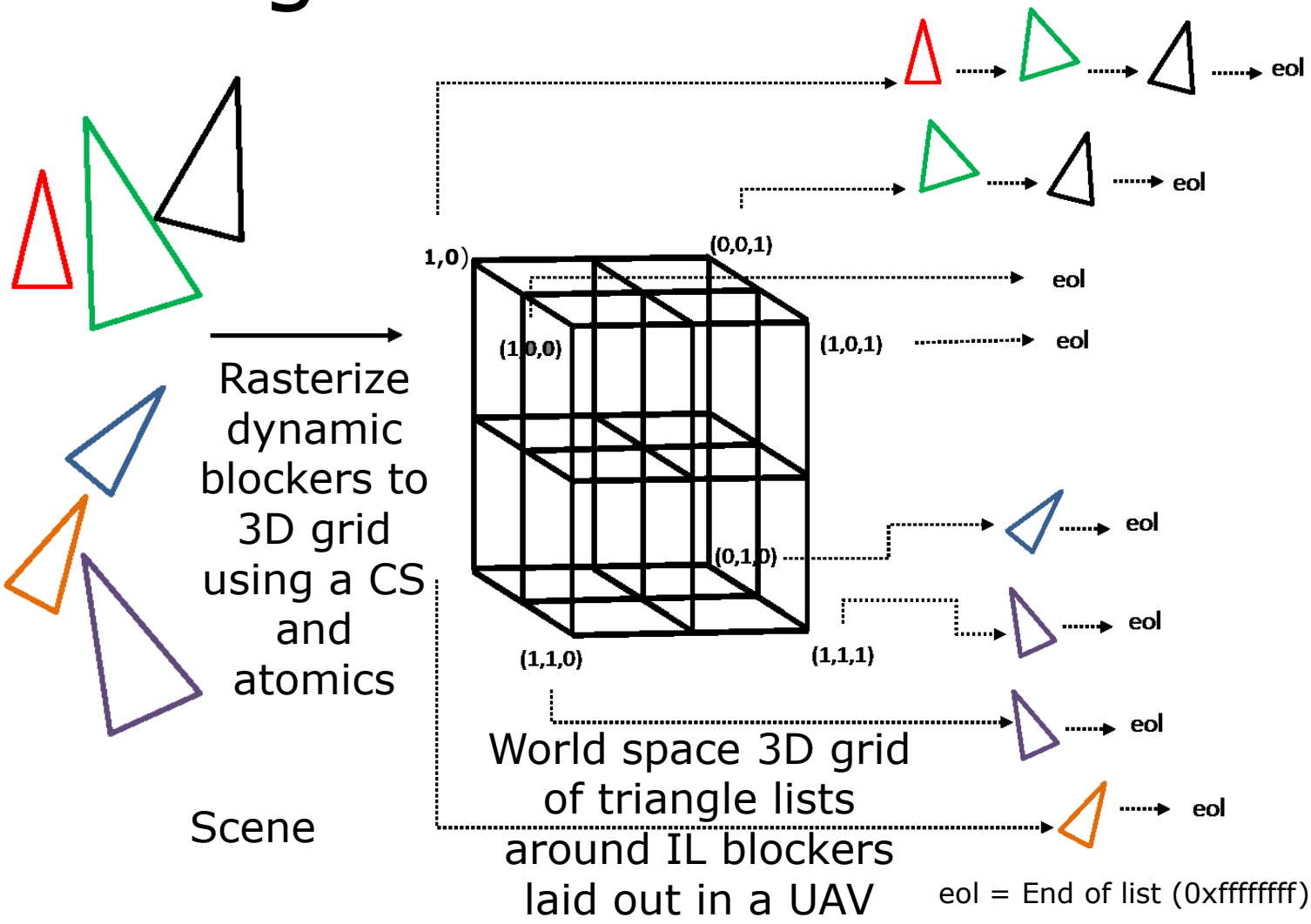


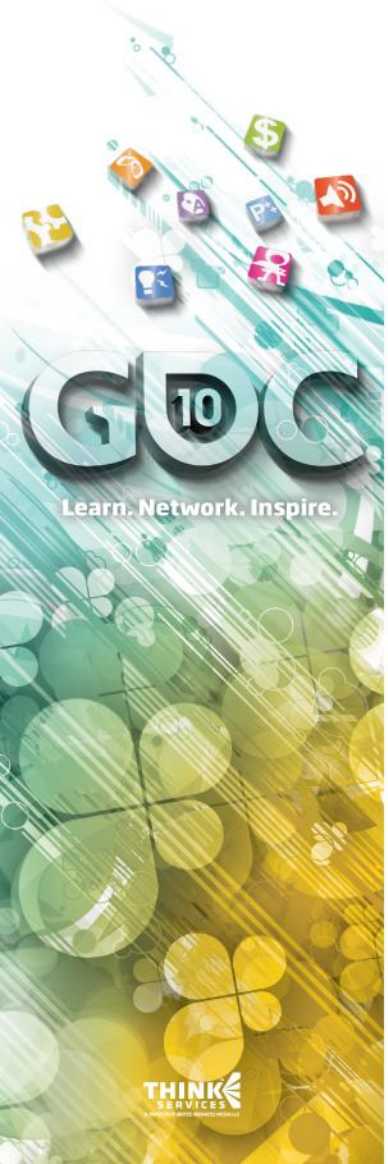
Rasterize dynamic blockers to 3D grid using a CS and atomics

Scene

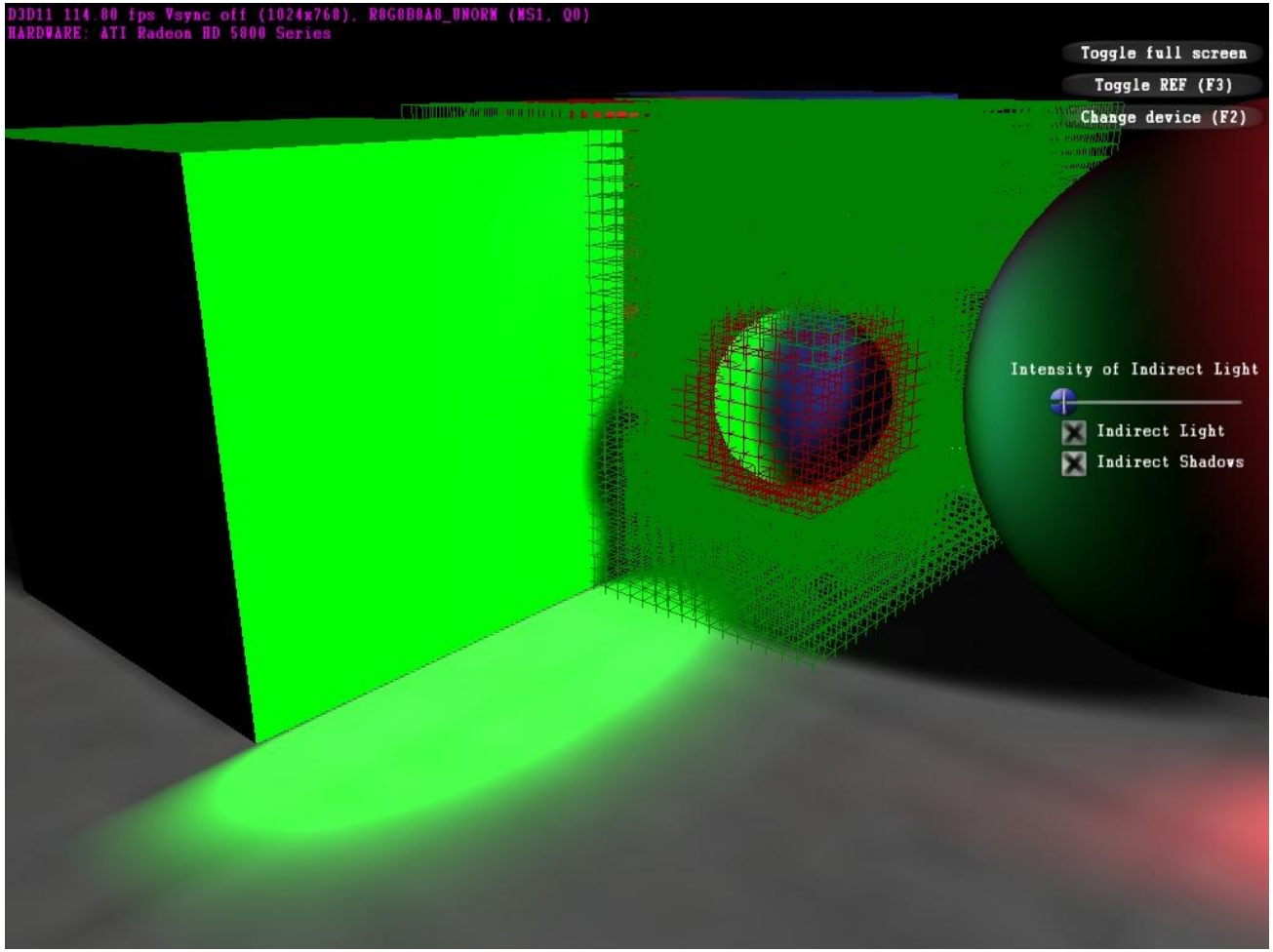
Insert tris into 3D grid of triangle lists

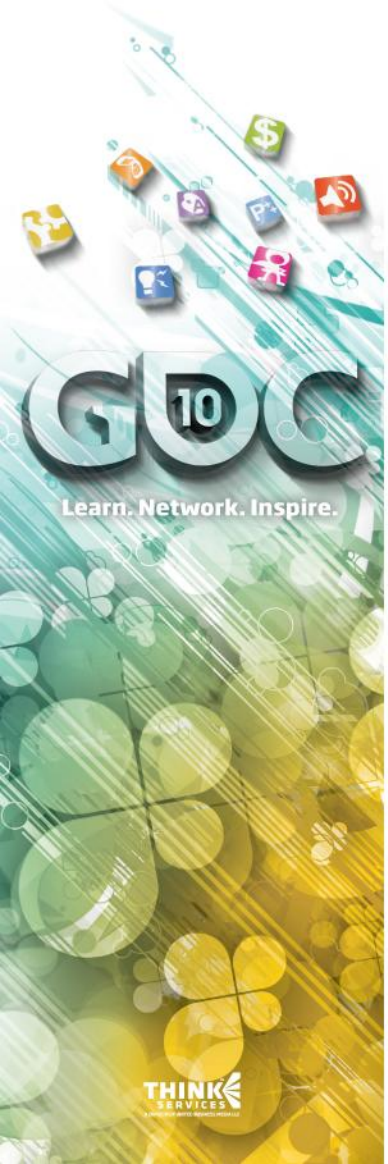




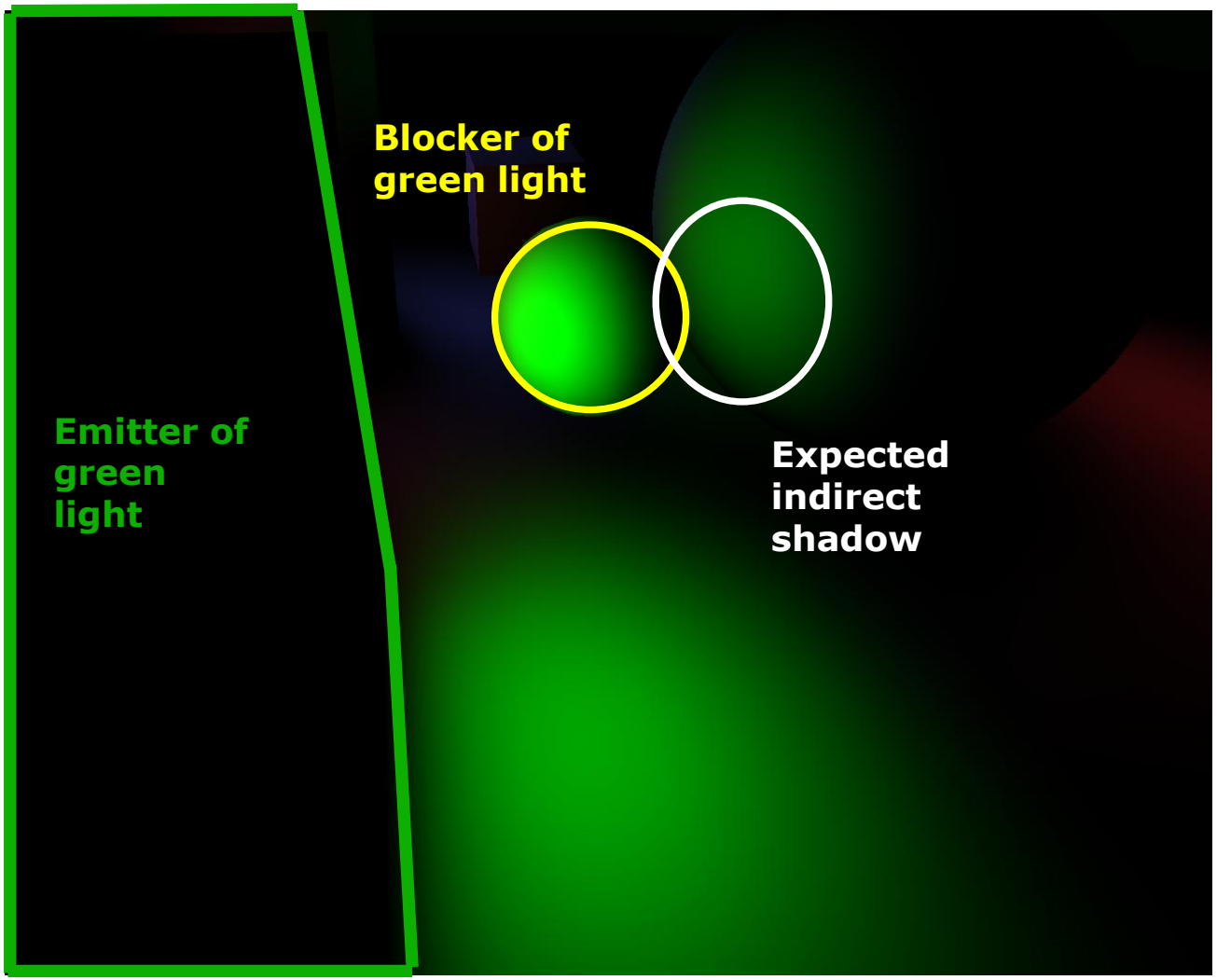


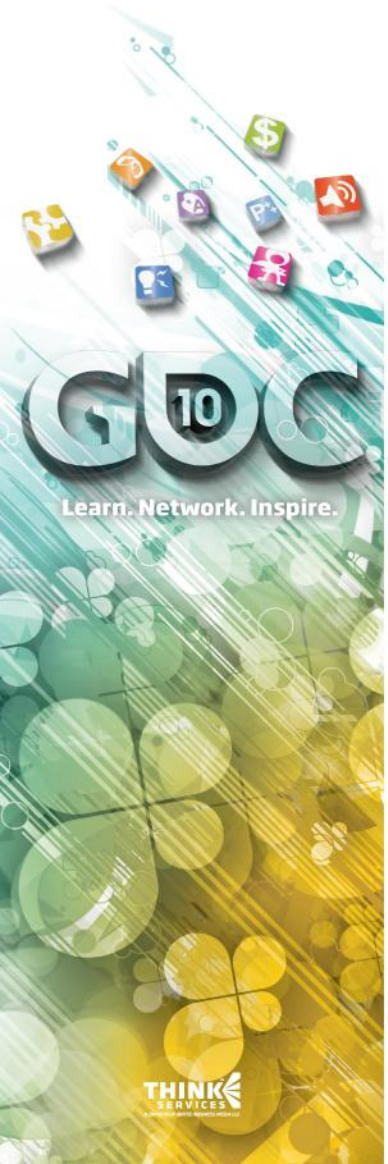
3D Grid Demo



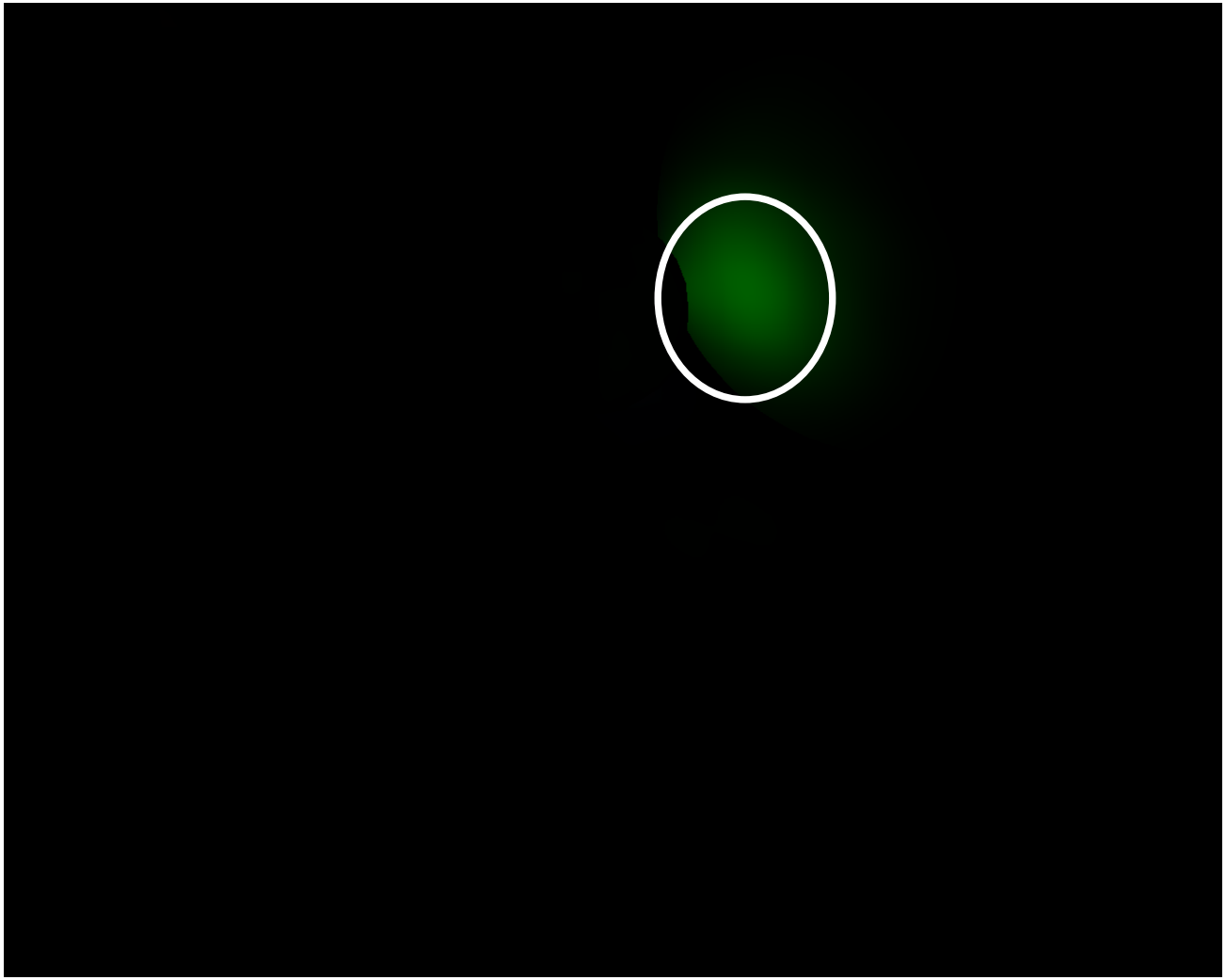


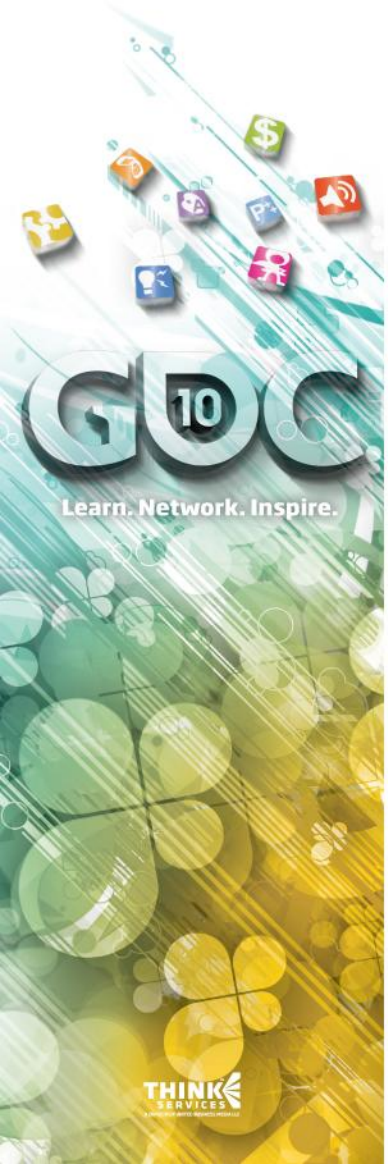
Indirect Light Buffer



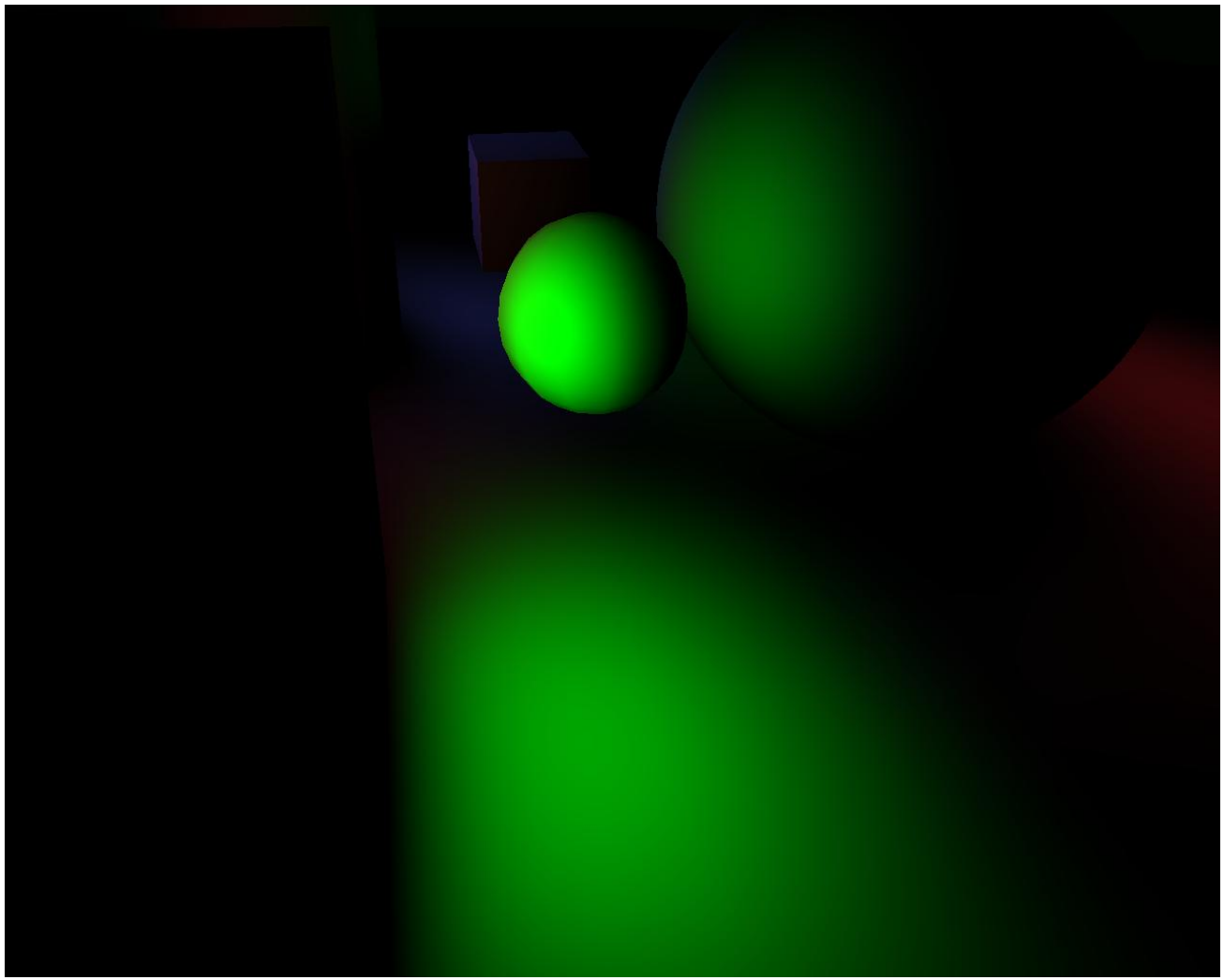


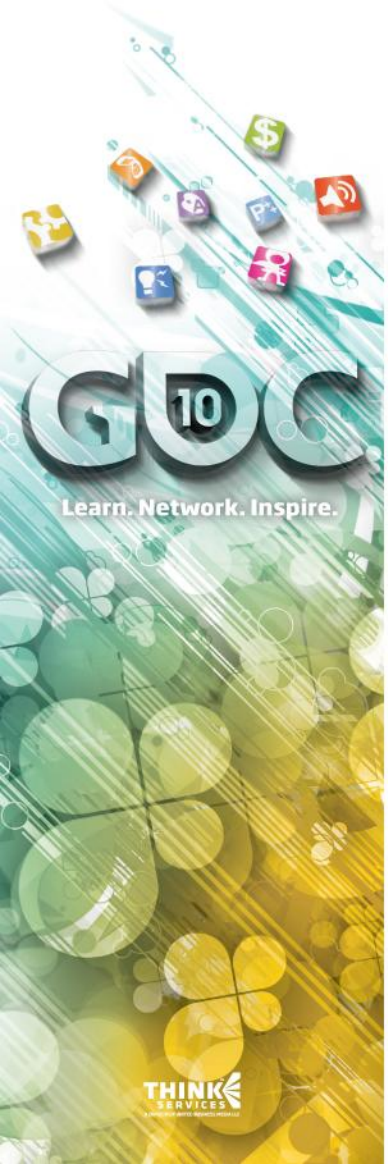
Blocked Indirect Light



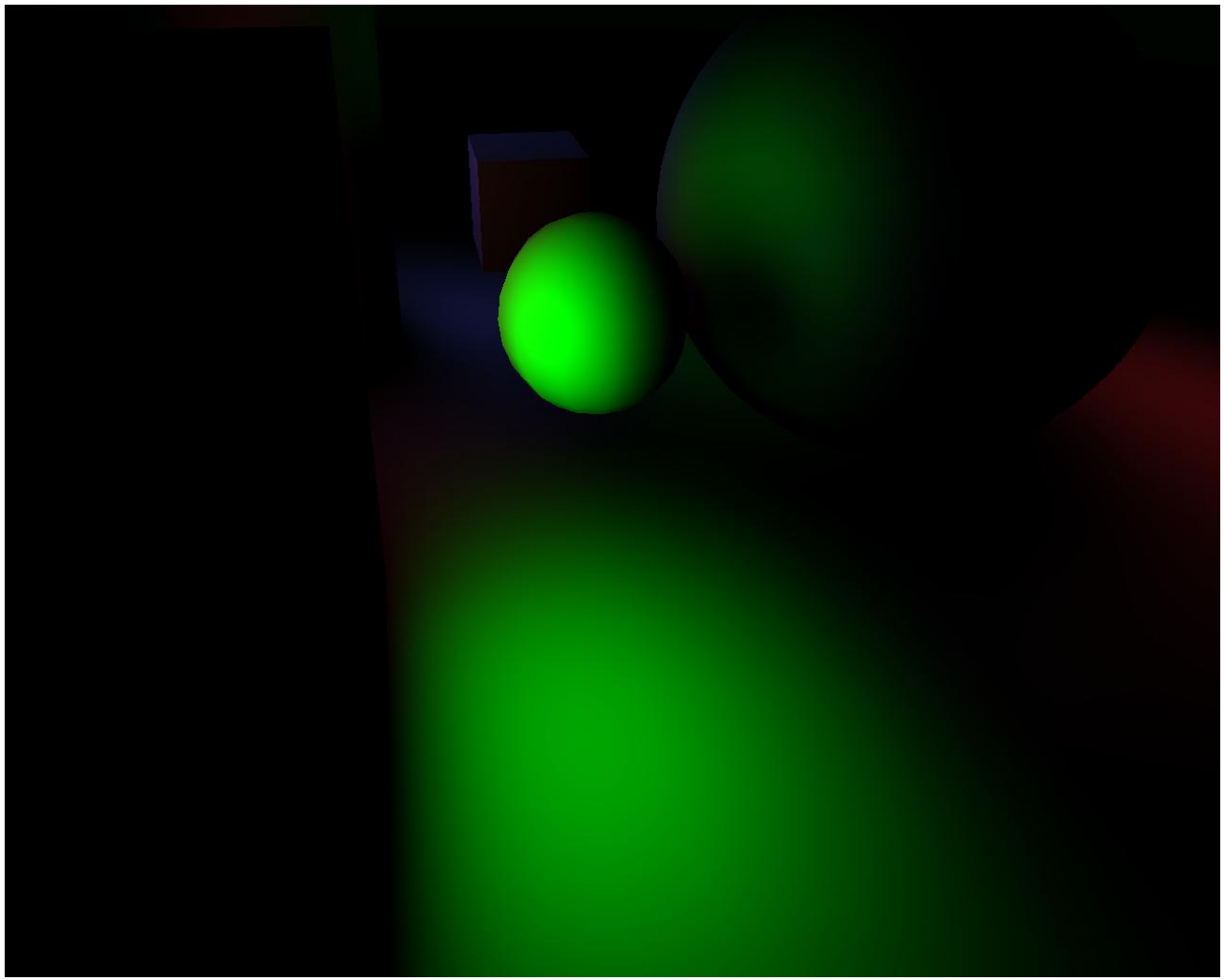


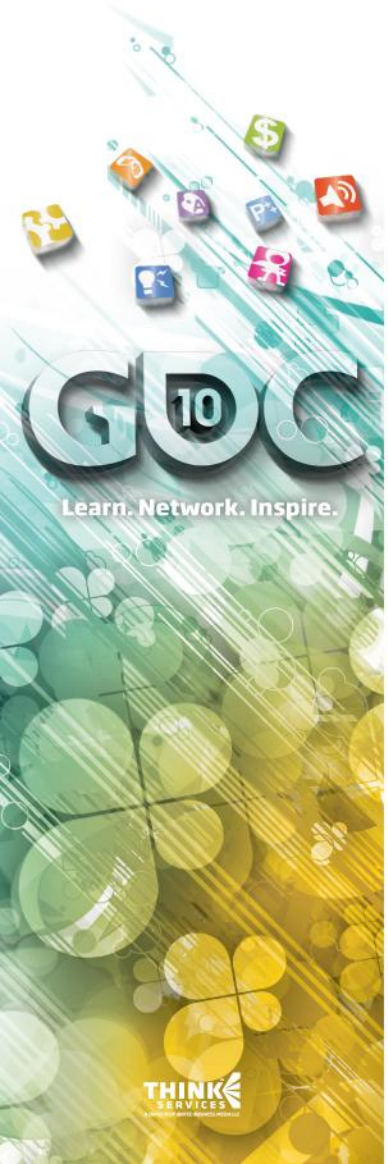
Indirect Light Buffer



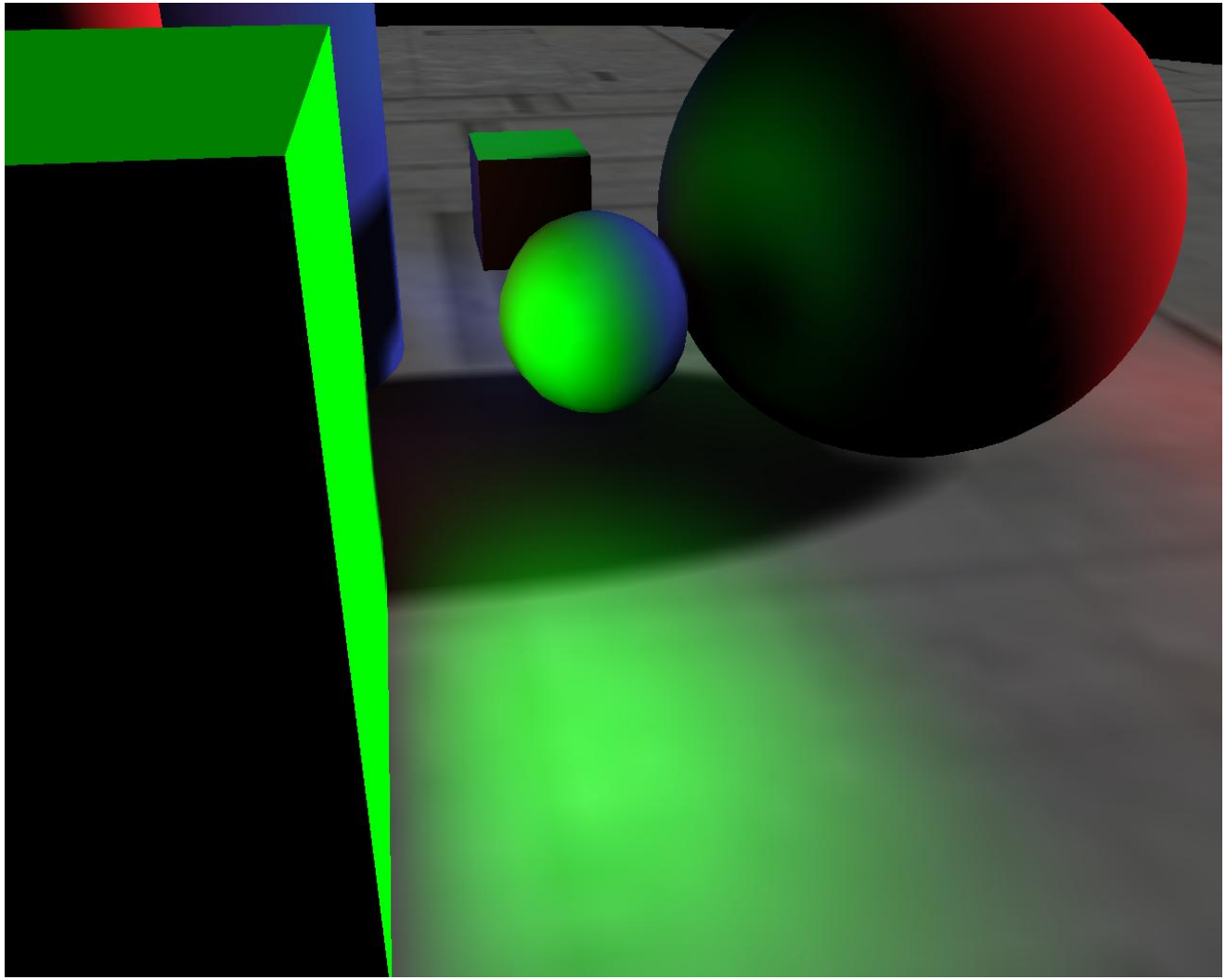


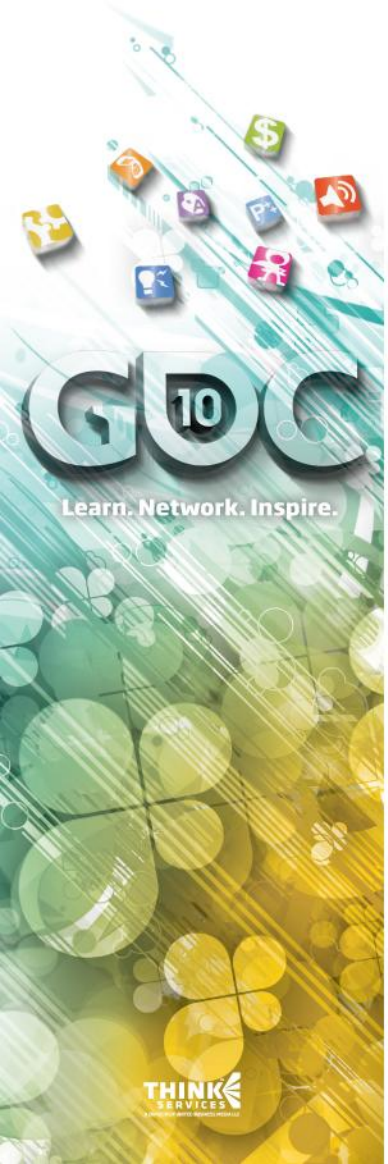
Subtracting Blocked IL



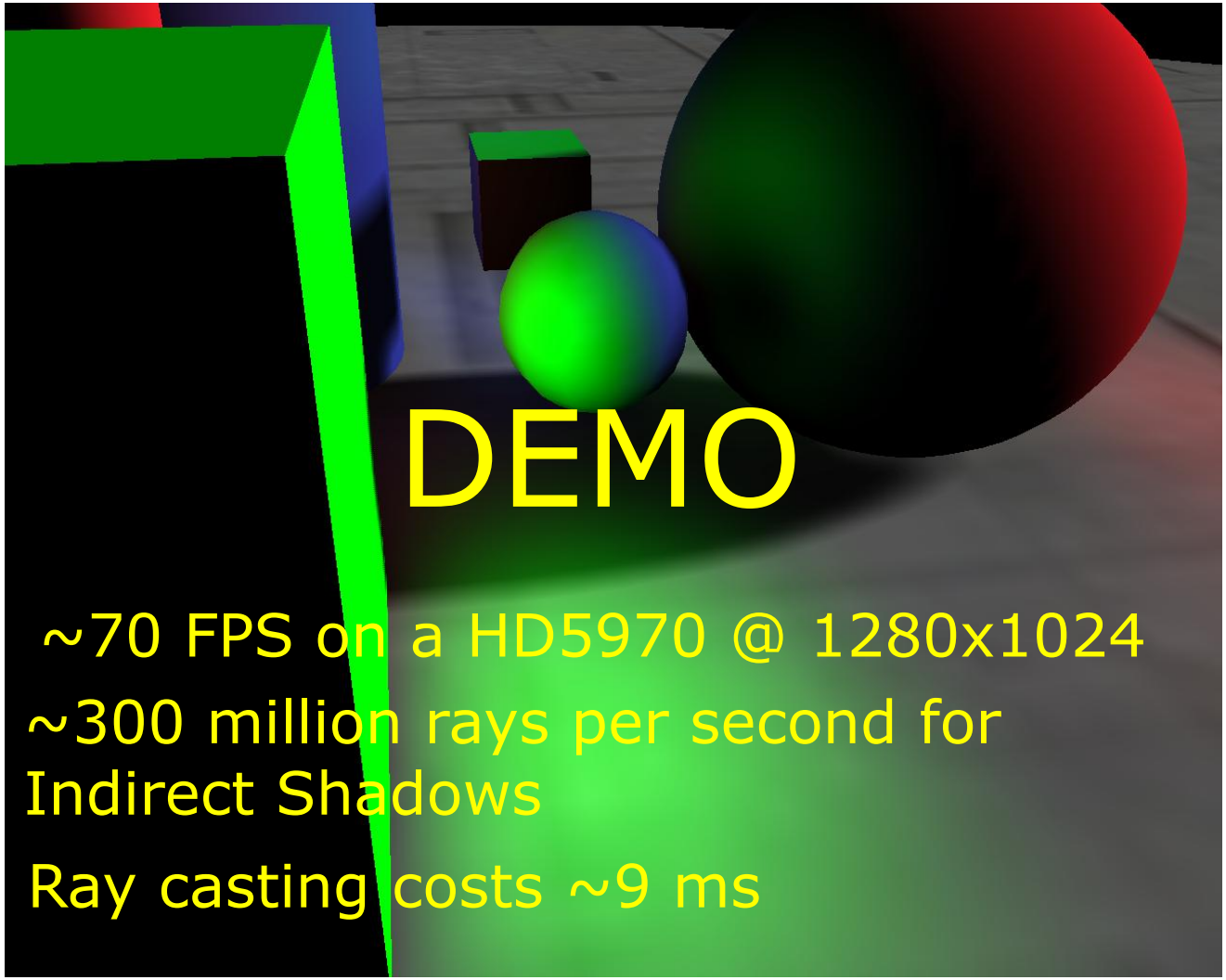


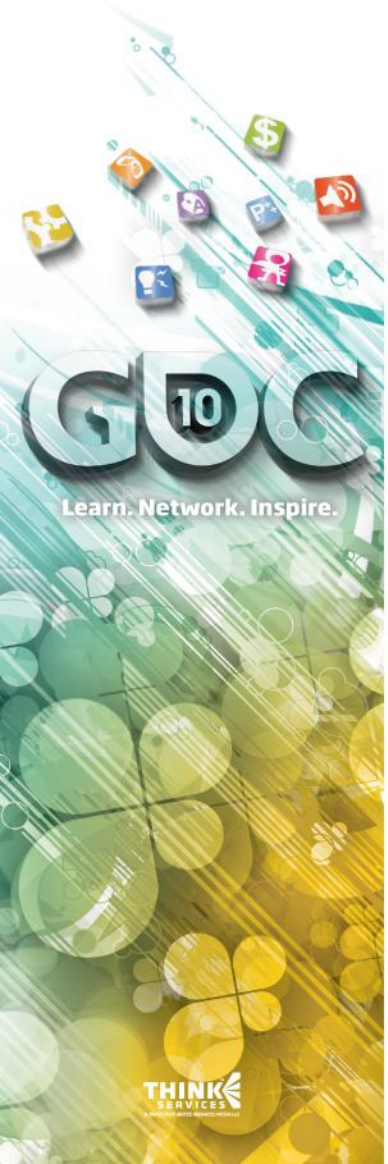
Final Image





Final Image





Future directions

- Speed up IL rendering
  - Render IL at even lower res
  - Look into multi-res RSMs
- Speed up ray-tracing
  - Per pixel array of lists for depth buckets (see backup)
  - Other data structures
- Raytrace other primitive types
  - Splats, fuzzy ellipsoids etc.
  - Proxy geometry or bounding volumes of blockers
- Get rid of Interlocked*() ops
  - Just mark grid cells as occupied => >150 fps
  - Lower quality but could work on earlier hardware through scattered splats

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March 9-13, 2010
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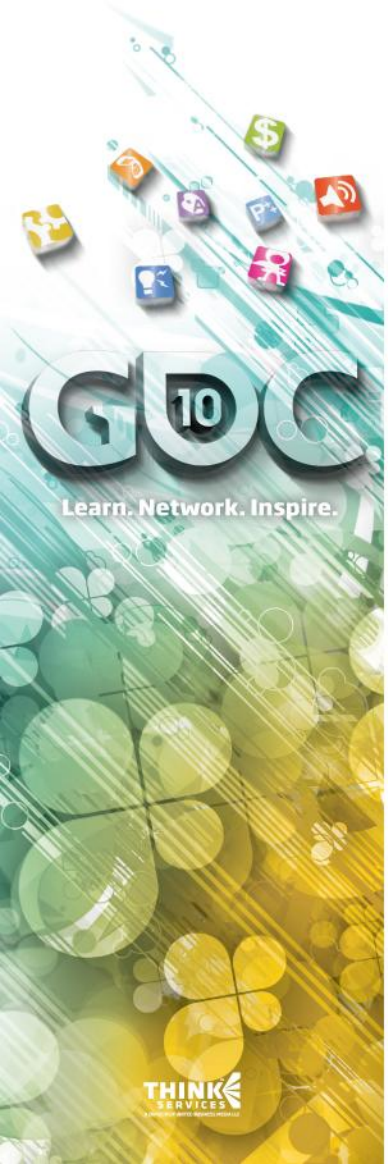

Q&A

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Nicolas Thibieroz nicolas.thibieroz@AMD.com

Credits for the basic idea of how to implement PPLL under Direct3D 11 go to Jakub Klarowicz (Techland), Holger Gruen and Nicolas Thibieroz (AMD)

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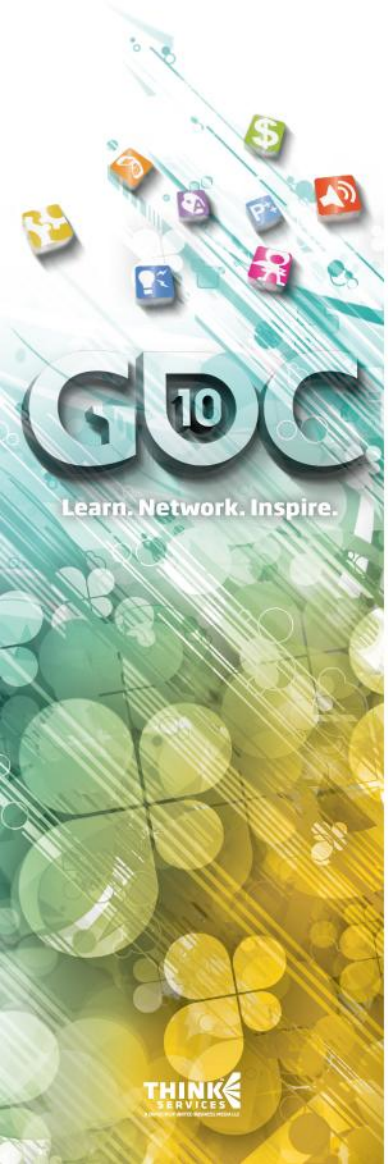
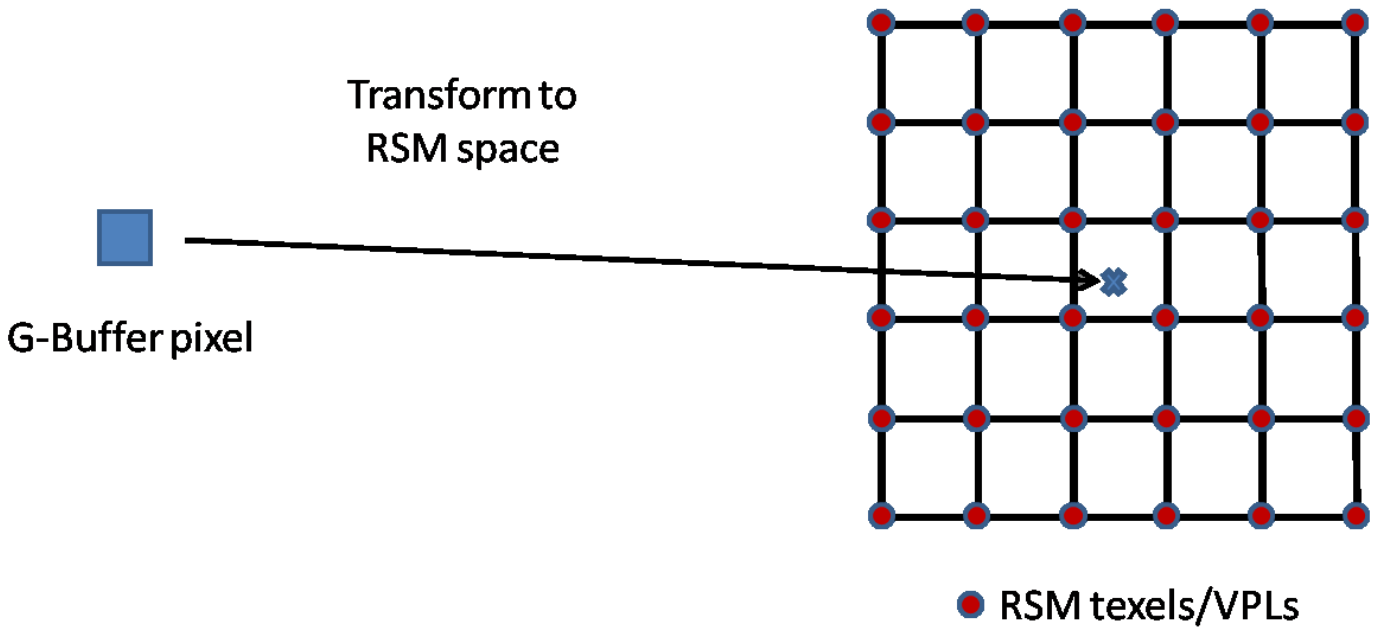
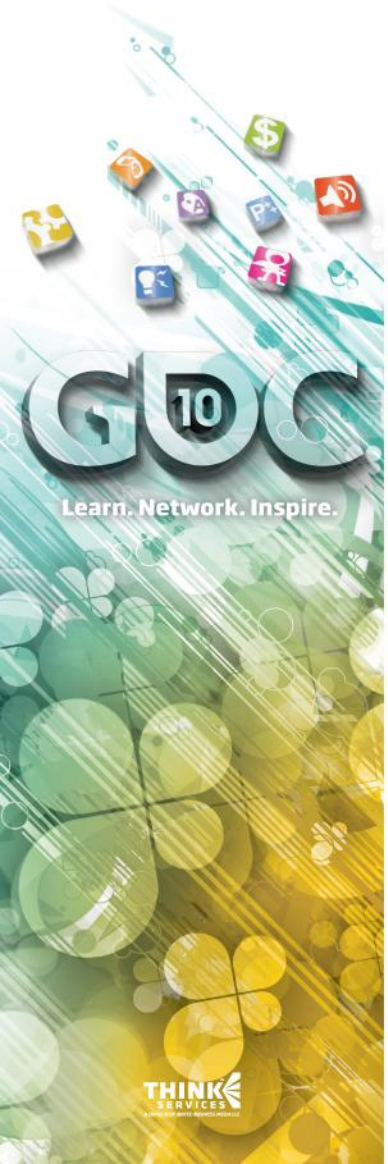
Backup Slides IL



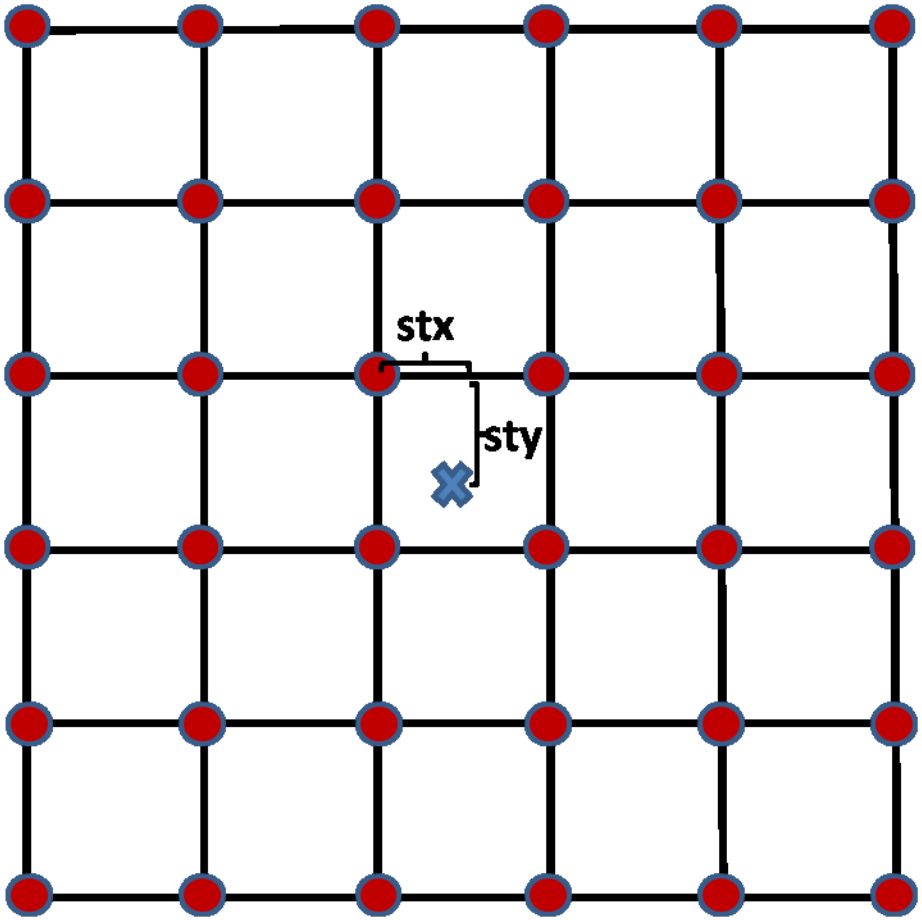
Computing IL at a g-buf pixel 1



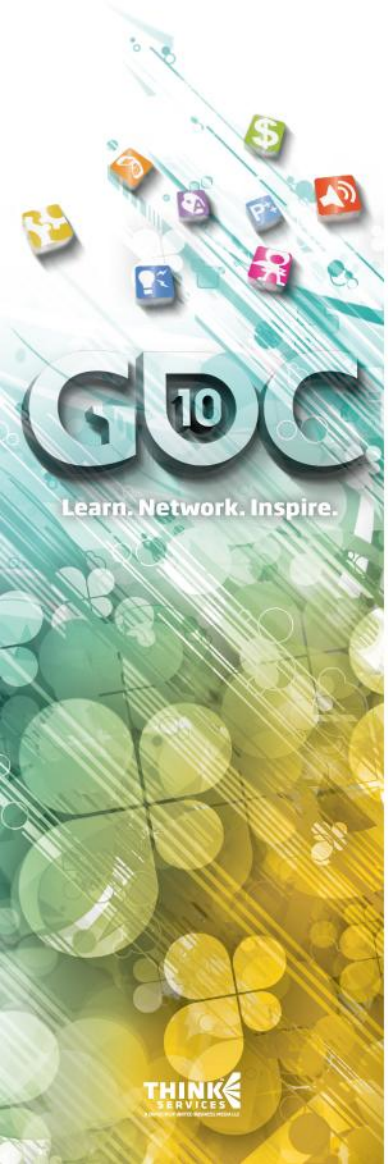
- Want to support low res RSMs
- Want to create smooth indirect light
- Goal is bi-linear filtering of four VPL-Kernels
  - Otherwise results don't look smooth



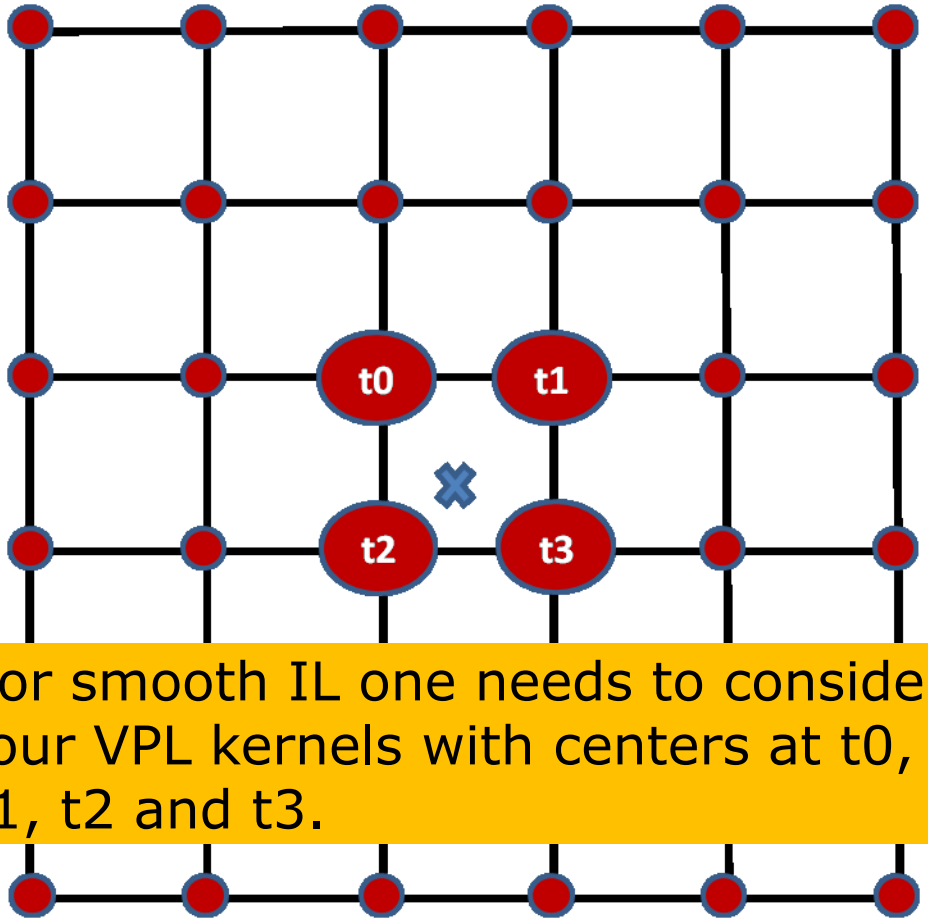
Computing IL at a g-buf pixel 2



stx : sub texel x position [0.0, 1.0[
sty : sub texel y position [0.0, 1.0[



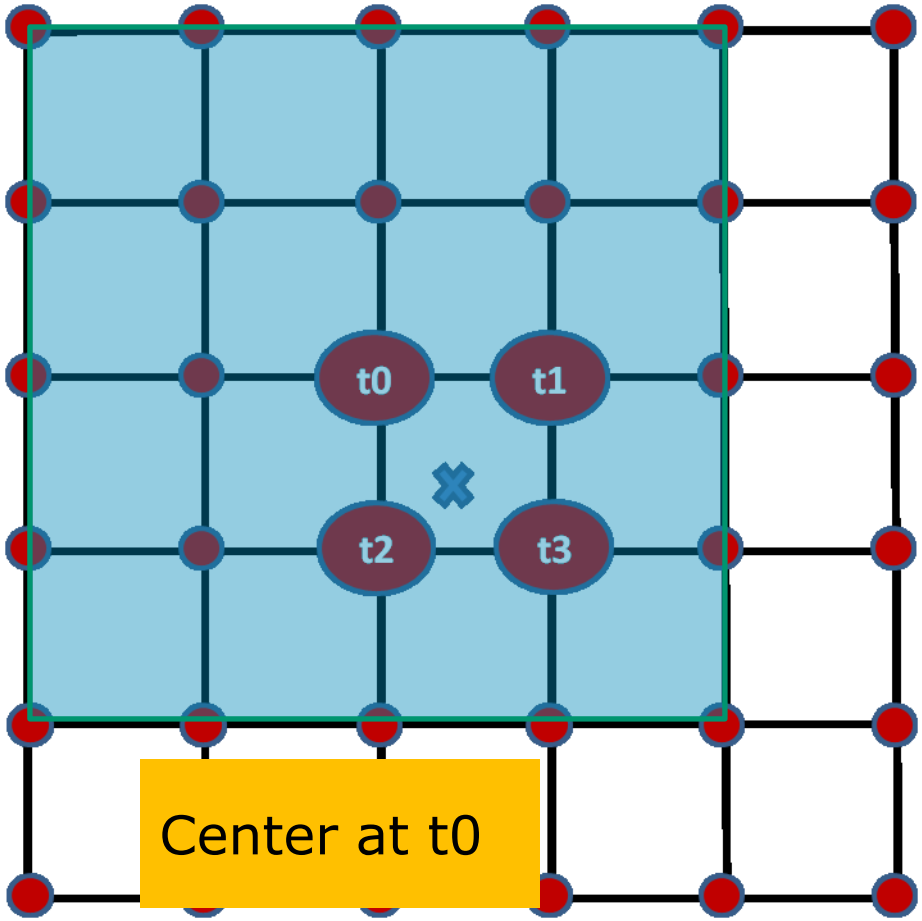
Computing IL at a g-buf pixel 3



For smooth IL one needs to consider four VPL kernels with centers at t0, t1, t2 and t3.

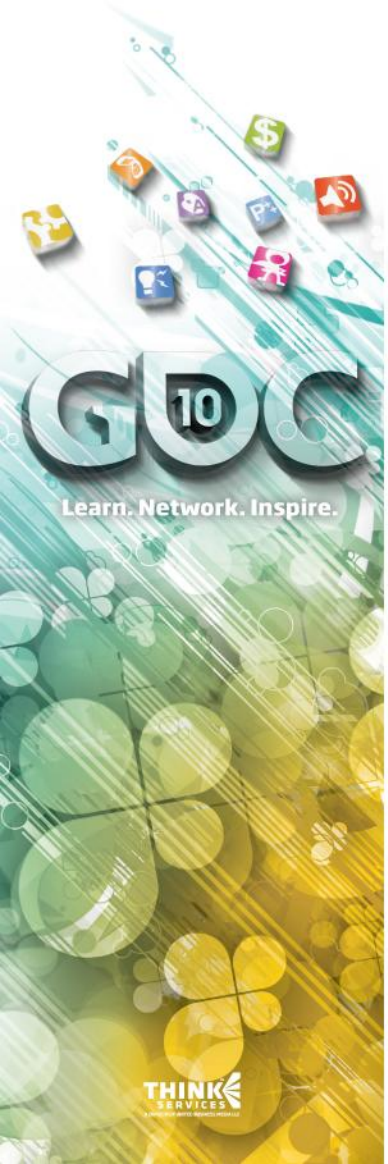
stx : sub texel x position [0.0, 1.0[
sty : sub texel y position [0.0, 1.0[

Computing IL at a g-buf pixel 4

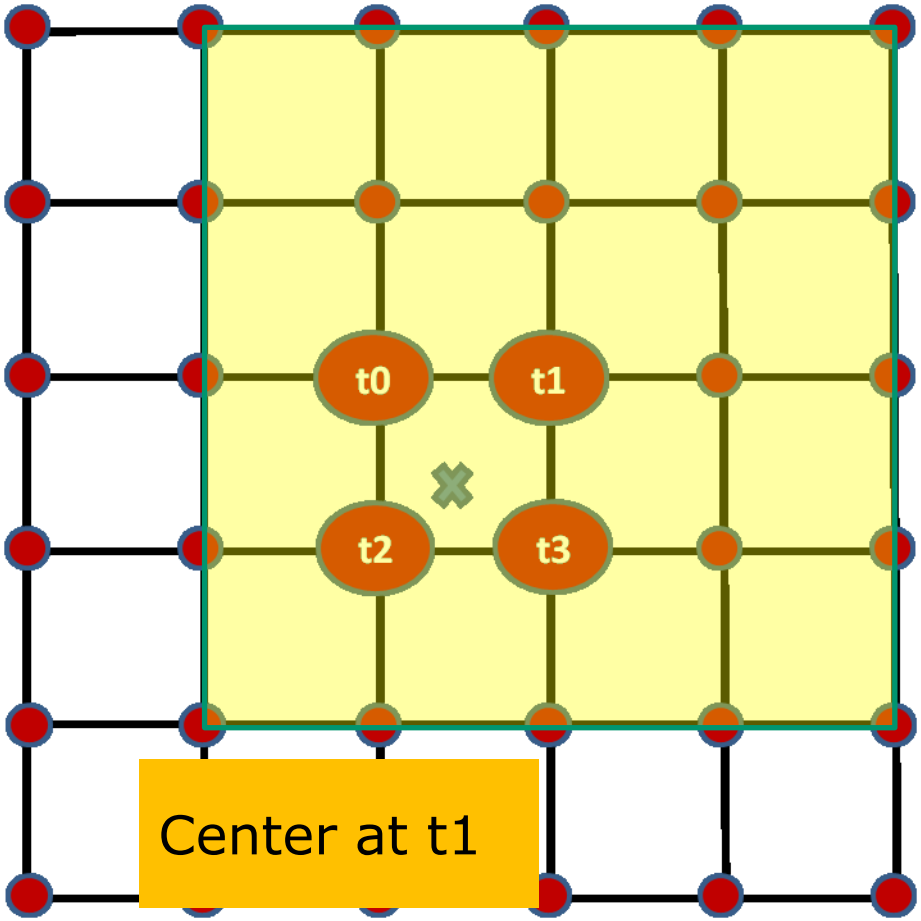


stx : sub texel x position [0.0, 1.0[
sty : sub texel y position [0.0, 1.0[

VPL kernel at **t0**

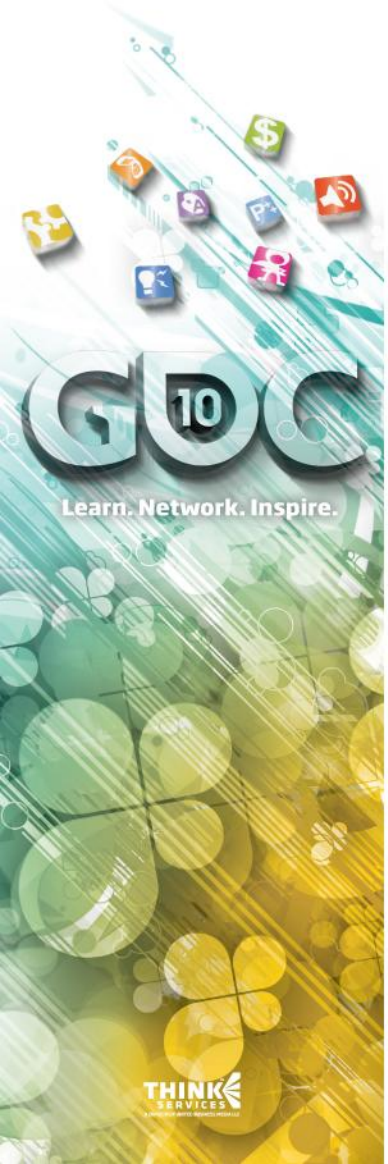


Computing IL at a g-buf pixel 4

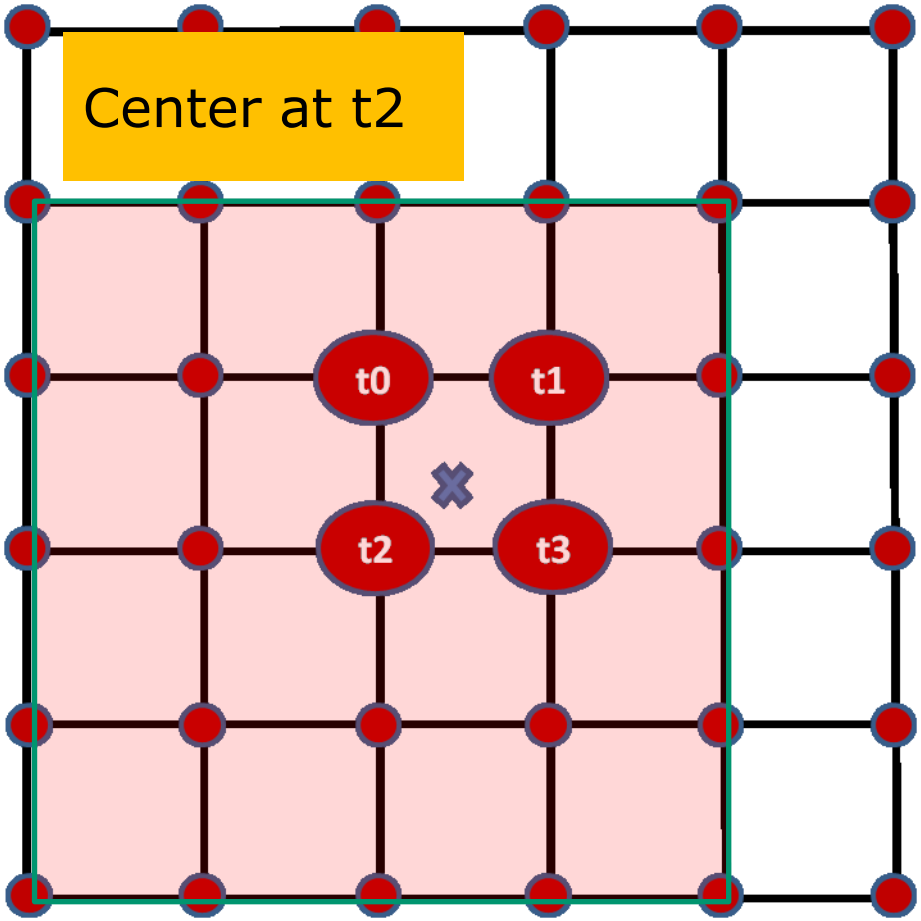


stx : sub texel x position [0.0, 1.0[
sty : sub texel y position [0.0, 1.0[

VPL kernel at **t0**
VPL kernel at **t1**

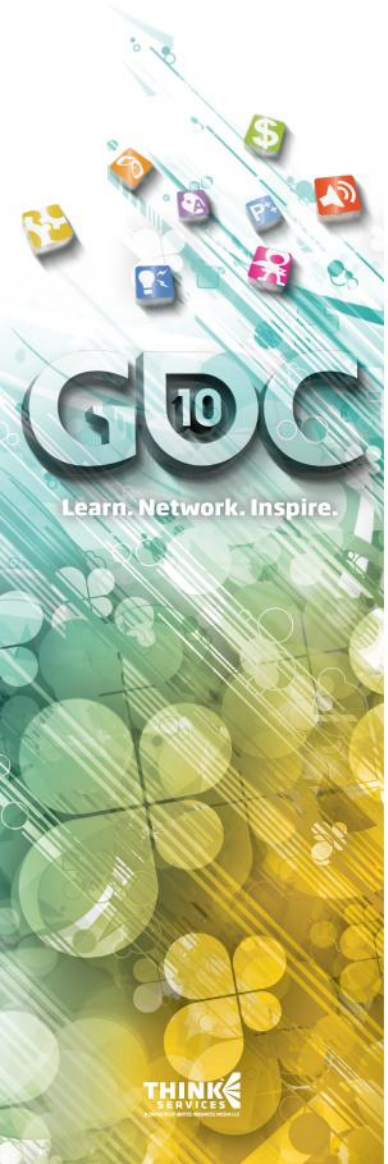


Computing IL at a g-buf pixel 5

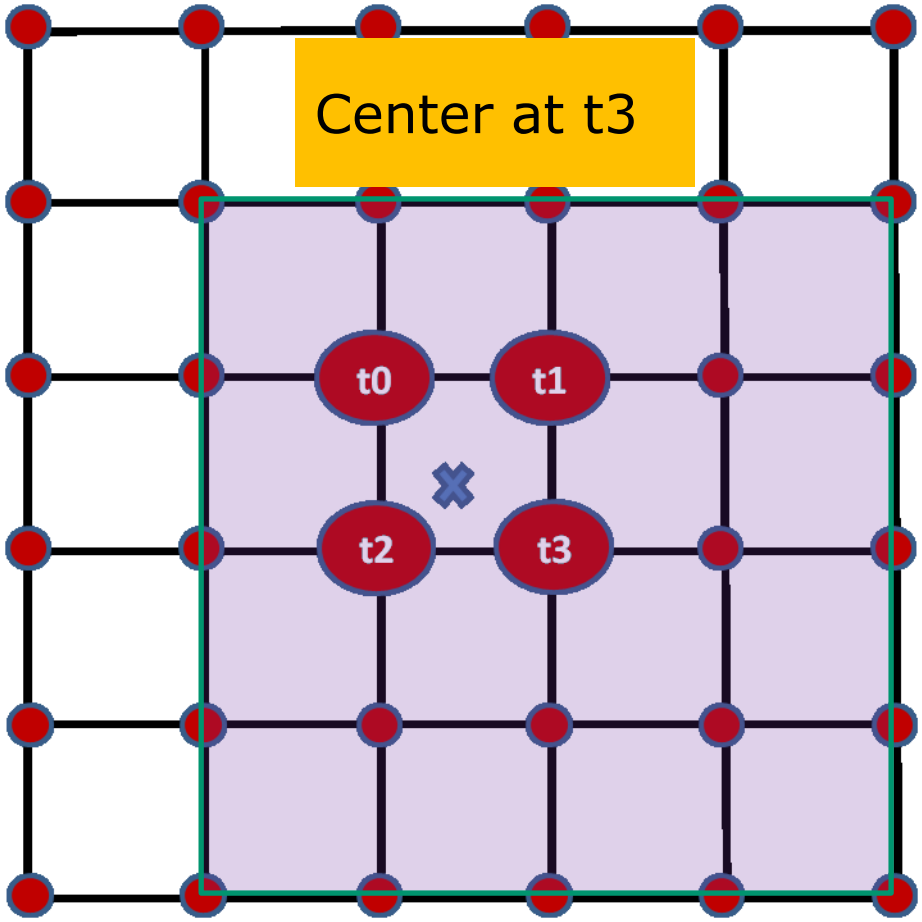


stx : sub texel x position [0.0, 1.0[
sty : sub texel y position [0.0, 1.0[

VPL kernel at **t0**
VPL kernel at **t1**
VPL kernel at **t2**

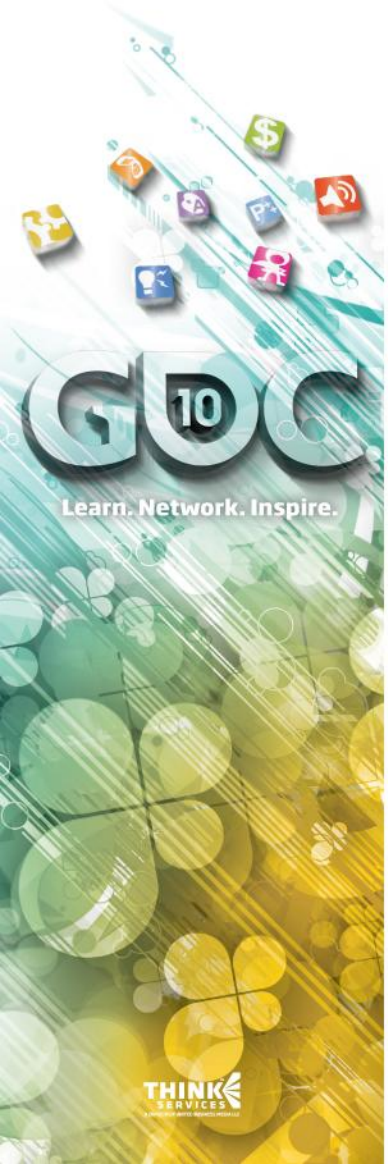


Computing IL at a g-buf pixel 6

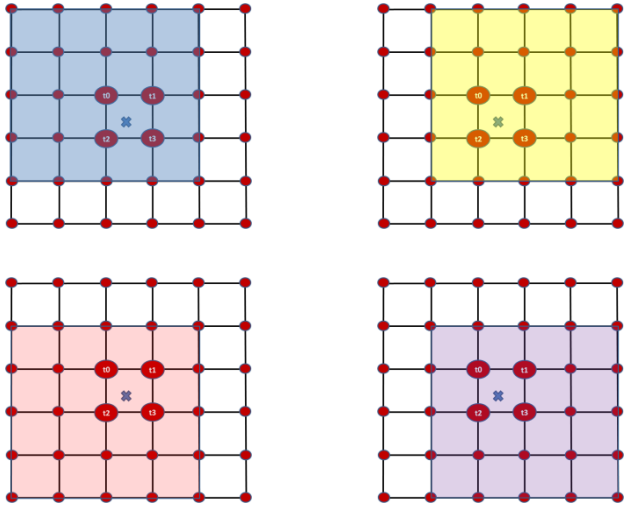


stx : sub texel x position [0.0, 1.0[
sty : sub texel y position [0.0, 1.0[

VPL kernel at **t0**
VPL kernel at **t1**
VPL kernel at **t2**
VPL kernel at **t3**



Computing IL at a g-buf pixel 7

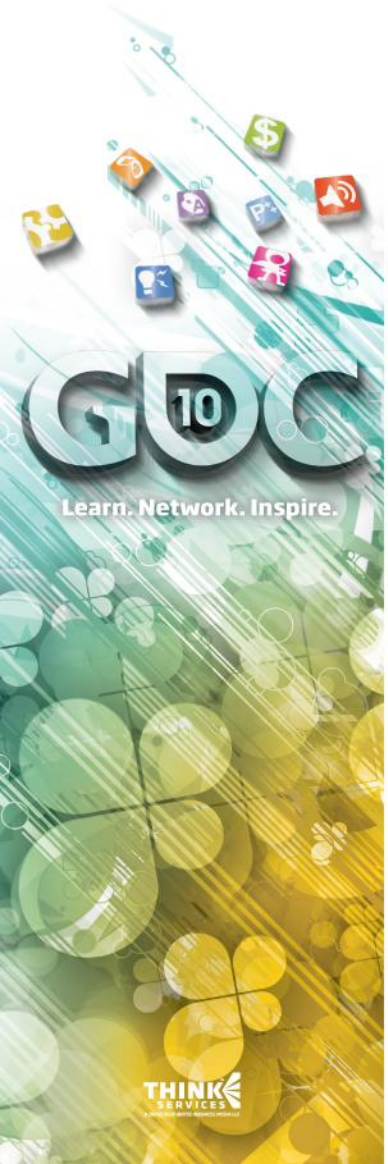


IndirectLight = (1.0f-sty) * ((1.0f-stx) * ■ + stx * ■) +
(0.0f+sty) * ((1.0f-stx) * ■ + stx * ■)

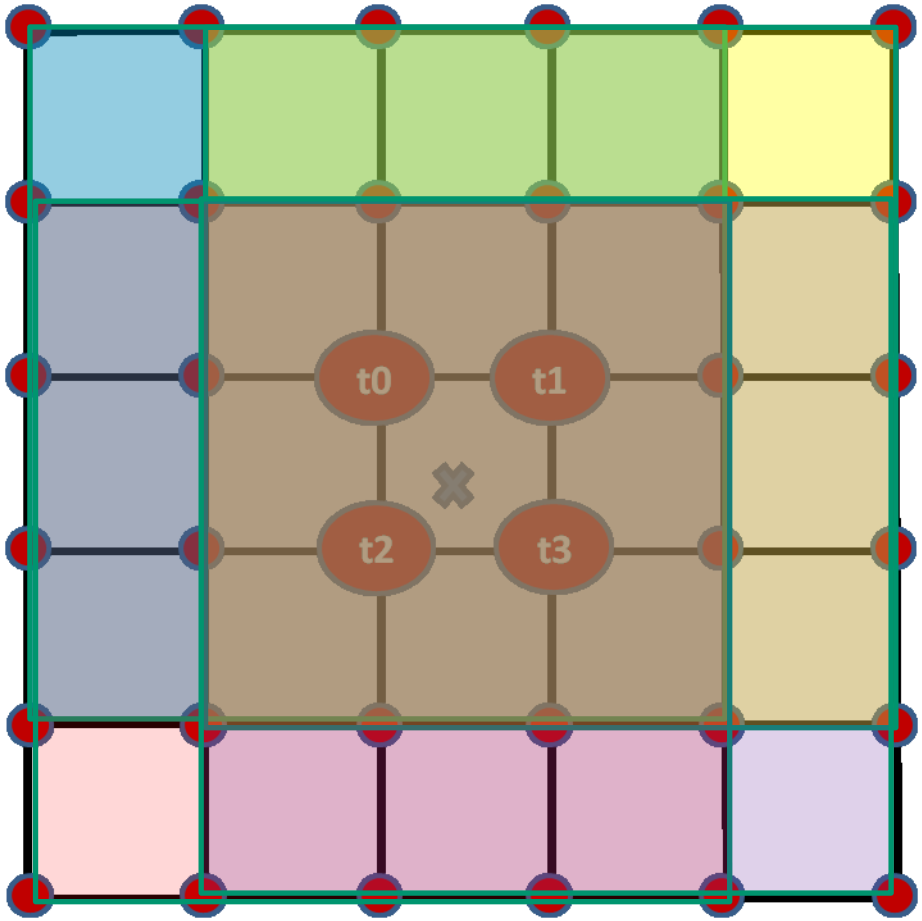
Evaluation of 4 big VPL kernels is slow ☹

stx : sub texel x position [0.0, 1.0[
sty : sub texel y position [0.0, 1.0[

■ VPL kernel at **t0**
■ VPL kernel at **t1**
■ VPL kernel at **t2**
■ VPL kernel at **t3**

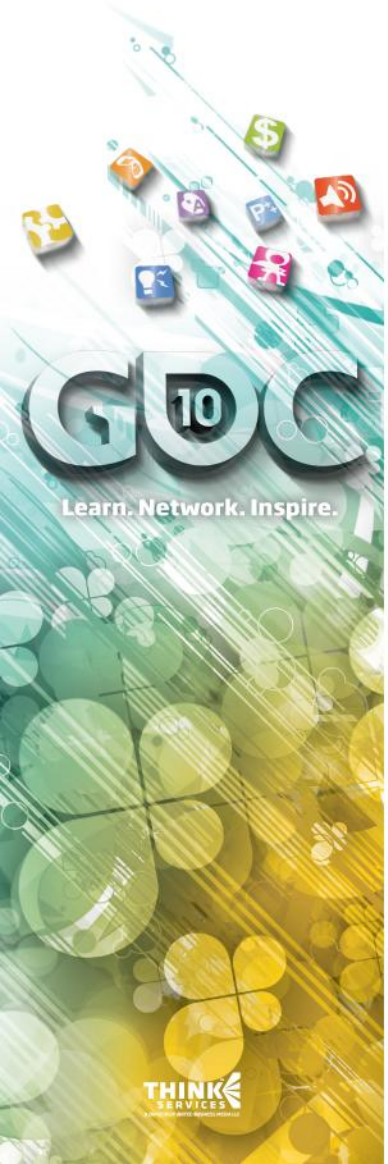


Computing IL at a g-buf pixel 8

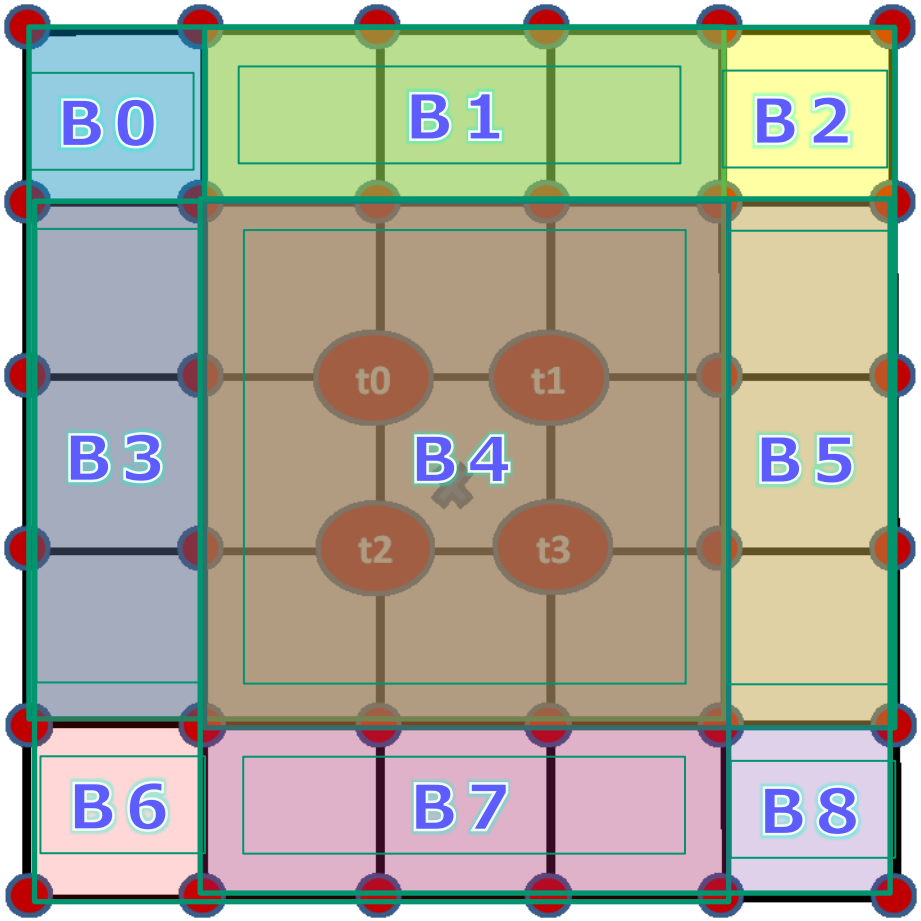


stx : sub texel x position [0.0, 1.0[
sty : sub texel y position [0.0, 1.0[

VPL kernel at **t0**
VPL kernel at **t2**
VPL kernel at **t1**
VPL kernel at **t3**

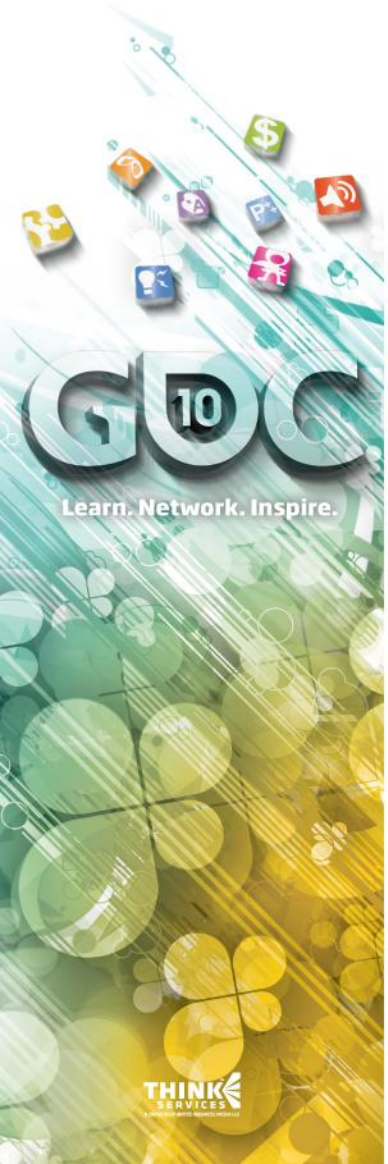


Computing IL at a g-buf pixel 9

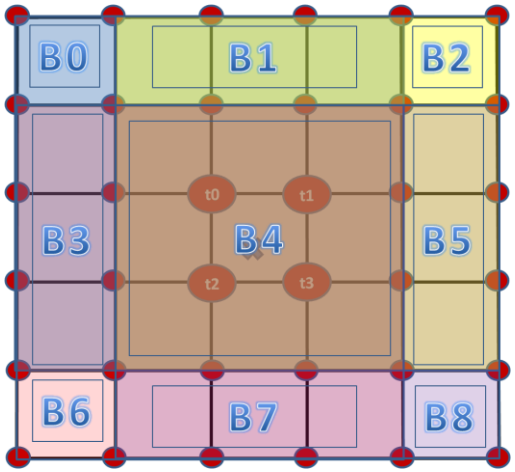


stx : sub texel x position [0.0, 1.0[
sty : sub texel y position [0.0, 1.0[

VPL kernel at **t0**
VPL kernel at **t1**
VPL kernel at **t2**
VPL kernel at **t3**



Computing IL at a g-buf pixel 9



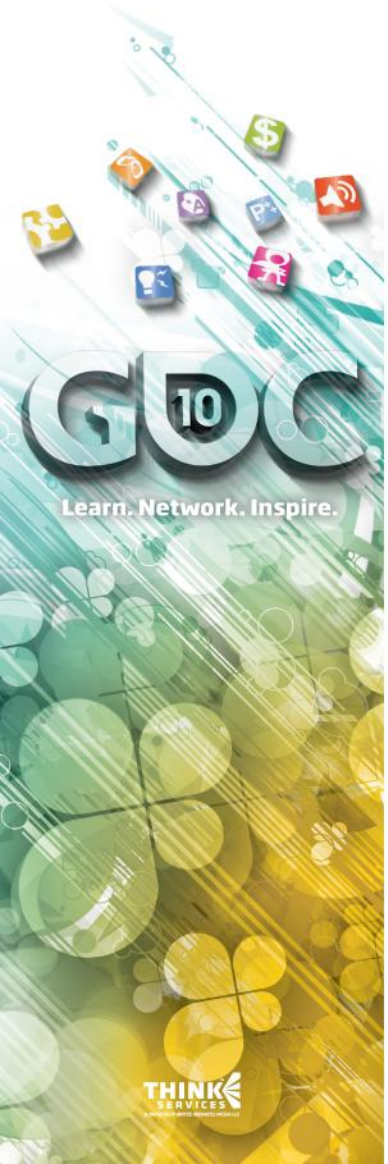
IndirectLight =

(1.0f-sty)*(((1.0f-stx)*(B0+B3)+stx*(B2+B5))+B1)+

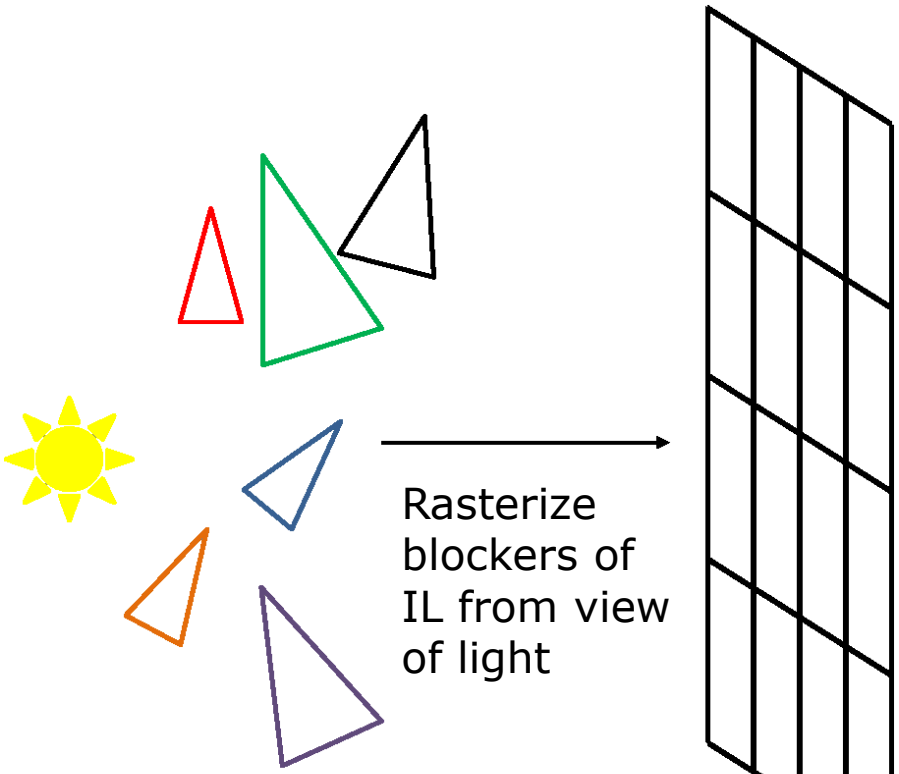
(0.0f+sty)*(((1.0f-stx)*(B6+B3)+stx*(B8+B5))+B7)+B4

Evaluation of 7 small and 1 bigger VPL kernels is fast ☺

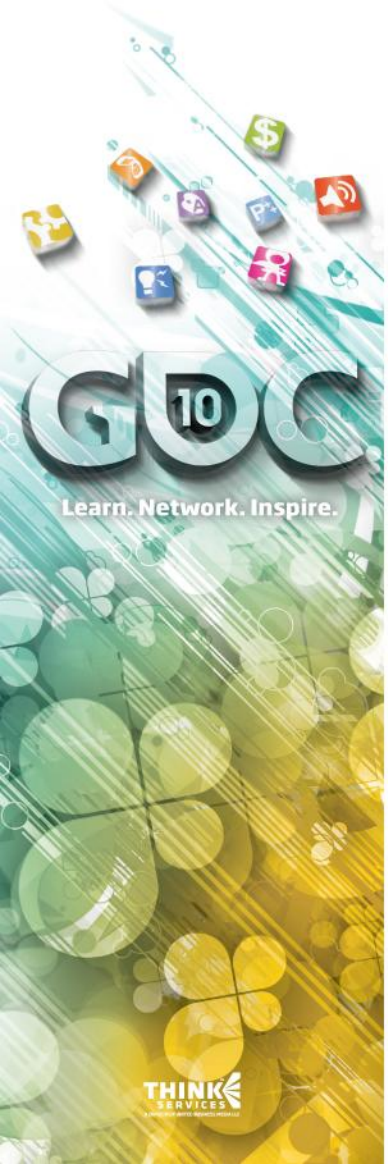
stx : sub texel x position [0.0, 1.0[
sty : sub texel y position [0.0, 1.0[



Insert Tris into 2D Map of Lists of Tris



Light Scene 2D buffer



Insert Tris into 2D Map of Lists of Tris