CUDA and the future of dynamic lighting

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Geomerics

- Introduction to Enlighten
- Enlighten CUDA runtime
- Real-time area lights
- Dynamic object radiosity

Enlighten

- Enlighten is practical real-time global illumination
- Use at run-time to dynamically light your game
- Fast iteration of lighting design offline

Key titles


BATTLEFIELD 3
DICE


NEED FOR SPEED
THE RUN


EVE
ONLINE
INCARNA


QUANTUM
CONUNDRUM

Radiosity

- Without radiosity
  - Direct illumination plus a global ambient term
  - Image is very flat

- With radiosity
  - Real depth to image
  - Shadows filled in and coloured
  - Subtle gradients of shadows
  - Scene lit with only two lights (sun and skybox)

Enlighten goals

- Pre-computed quality with the flexibility of dynamic lighting
- Creative freedom for artists and designers
- Visual and atmospheric quality bar raised

Enlighten philosophy

- Target the current generation of hardware
  - Use lightmap techniques
  - All the complex calculations should take place in a single pre-processing step
- Keep the technology modular
  - Separate the direct and indirect lighting
  - Separate static and dynamic objects
- Keep the runtime as lightweight and simple as possible
  - See this with CUDA implementation

Runtime Philosophy

- Memory and compute power are contested commodities on PS3 and Xbox360
- Look at a range of optimisation strategies
  - Light a simplified mesh and project
  - Use temporal coherence
  - Stream the calculations
- Originally thought Enlighten would run on GPU, but changed direction for consoles

Design Philosophy

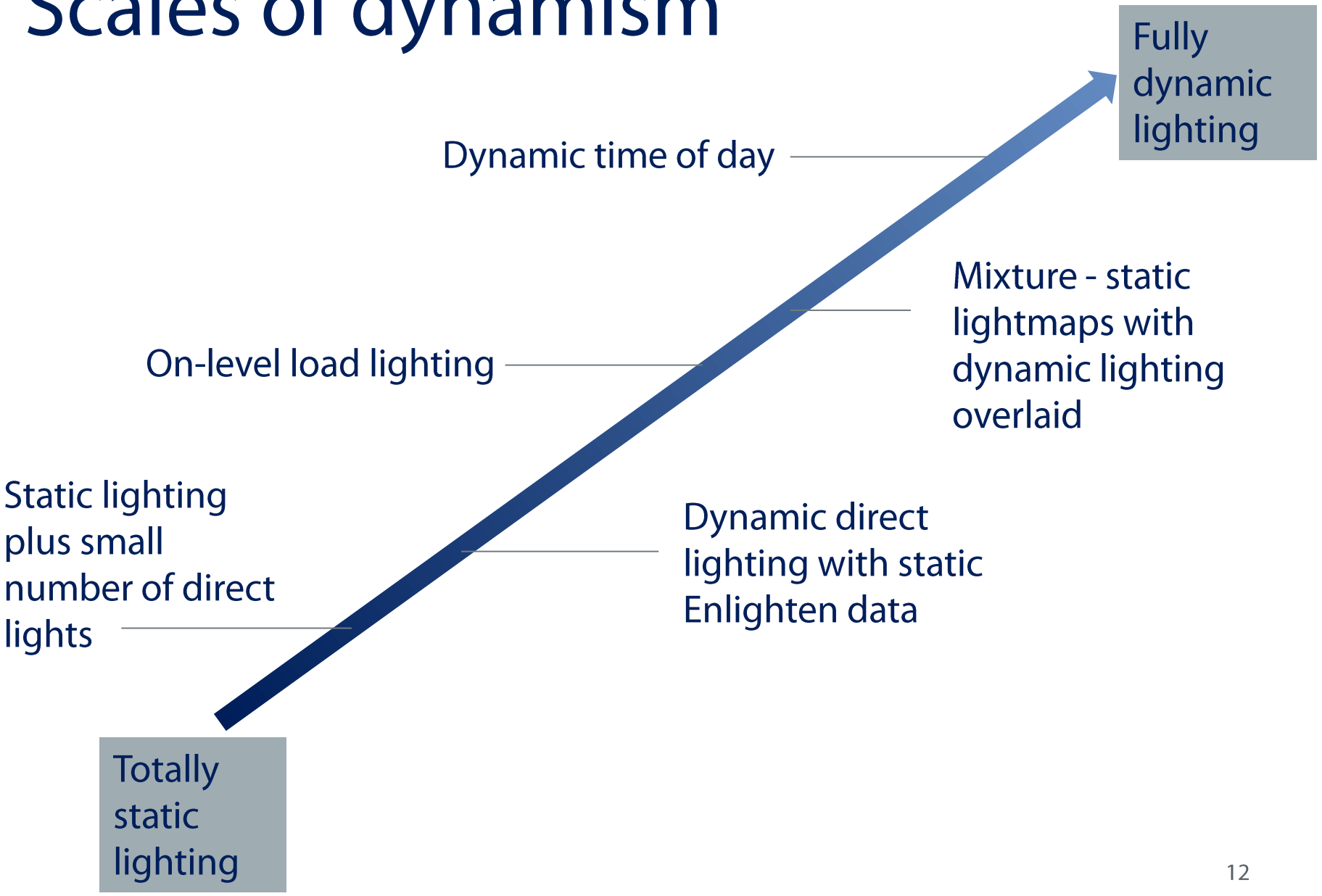
- Enlighten had to scale to all possible scenarios:
  - Interiors
  - Enclosed areas
  - Entire cities

Design Philosophy

- Put the artist in control
  - Instant feedback
  - As many knobs & dials as possible
- You can break the laws of physics
  - Why stick to realistic lighting?

The hardware zoo

Scales of dynamism



Reaching all games

- Current consoles fully capable of real-time dynamic lighting
  - This is our base point
- Next-gen preparation on high end PC
  - DX11 / CUDA Features
- Scale back to mobile with hybrid static / dynamic solutions
  - Enlighten runtime ported to ARM architecture
  - Augment with ability to bake

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What is CUDA?

- Most advanced platform/language for GPGPU
- Widely used in scientific applications
- C-like language for massively parallel execution
- Units of execution (functions) are called "kernels"
- A kernel is launched on a grid of blocks of threads
- Need 10,000s of threads to fill up a graphics card

CUDA and graphics

- CUDA can inter-operate with D3D and OpenGL
- Read from or write to graphics resources directly (textures, vertex buffers...)
- Removes need for CPU<->GPU transfer
- GPU can write to "pinned" CPU memory
- It's fast!
- Further efficiencies from inter-operability
  - Read from shadow maps directly

Enlighten run-time

- Input Lighting
  - Light a large number of point samples
  - Naturally very GPU-friendly!
  - Able to use all D3D resources as inputs
  - We will look into just doing this phase on GPU
- Output computation
  - Optimised for memory usage/throughput
  - Nearby pixels share data
  - This allows us to leverage features of CUDA

Blocks

- Kernels launched on grid of blocks
- Blocks typically hundreds of threads
- Important because:
  - Blocks execute within one streaming processor
  - Data can be synchronised and shared within a block
- Using shared memory is critical for performance

Demo

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Soft shadows

Techniques

- Fixed-size approaches
  - PCF, VSM, CSM, ESM (and others)
- Depth-varying approaches
  - PCSS and variants of fixed-sized versions
  - Largely based on average blocker depth
- Back projection approaches
  - Basis for this technique
- Ray tracing
  - One day…

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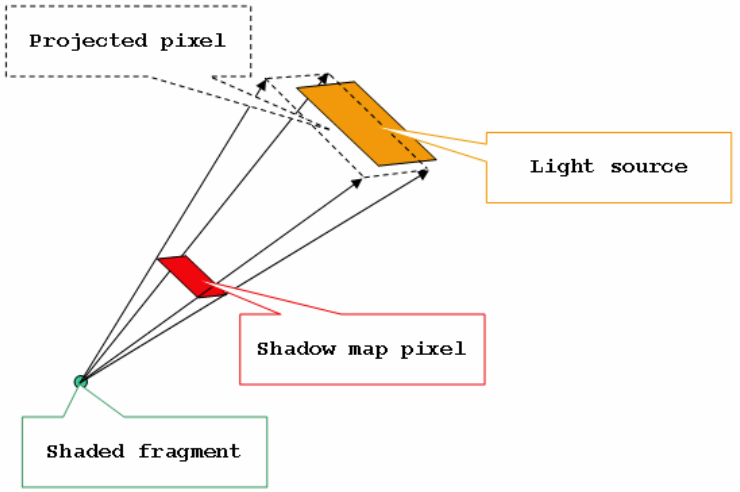
PCSS limitations

- Large penumbra are expensive
- Noisy if you under sample
- Correct only when average depth exists
- Large area lights push limits
- Artefacts when assumptions fail
- Shadows have a “geometric” look

Backprojection

- Use rectangular light source
- Consider texels in shadow map as occluders
- Find occluders between receiver and light source
- “Back project” to light source to compute occlusion
- Remaining area gives visibility factor



Bitmask Back Projection

- Bitmask Soft Shadows
  - Michael Schwarz, Marc Stamminger, (Computer Graphics Forum 2007)
  - Main variant of Guennebaud 2006.
- Occluders as continuous mesh of quads
- No gaps between occluders (+ and -)
- Fixes under occlusion, but projection more complex
- Use bit mask to represent visible area
- Slower, but fixes over occlusion

This technique

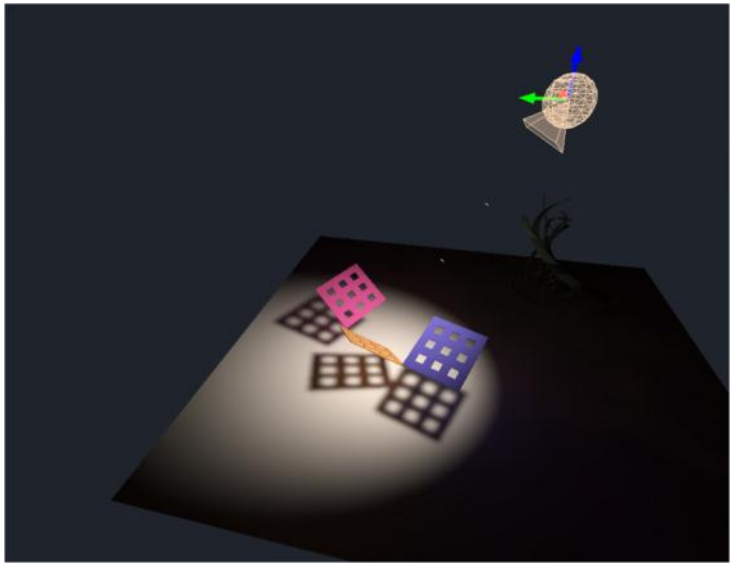
- Basis:
  - Occluders as continuous surface (a la Schwartz)
  - Support both bitmask and area-based variants
  - Adaptive subdivision (a la Dmitriev)

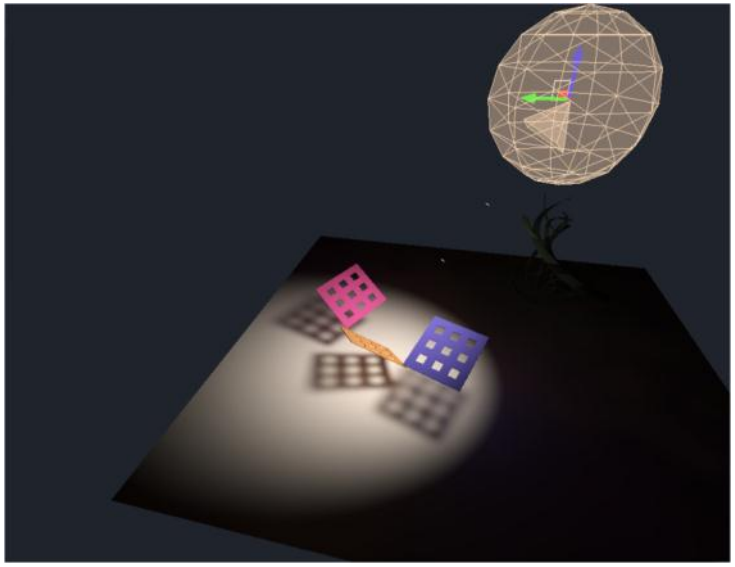
- Plus:
  - 5x5 tap screen-space bilateral reconstruction
  - Downsampled 3x3 symmetric SM hierarchy
  - Various bells and whistles

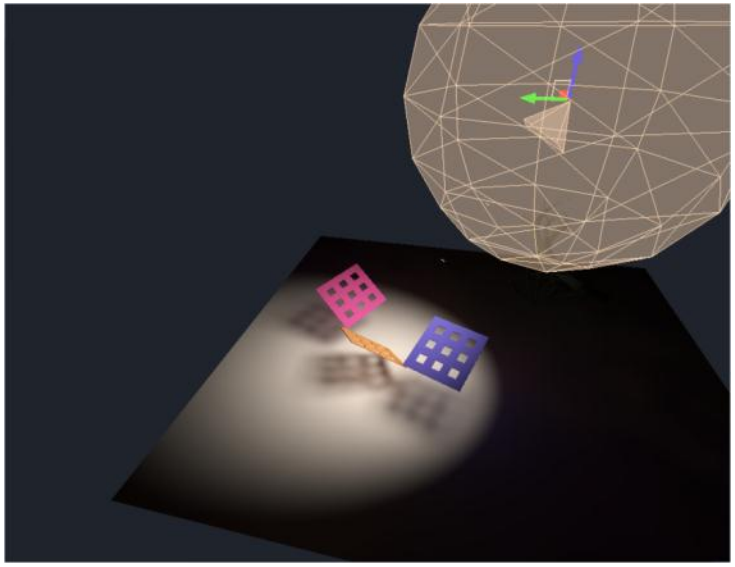
Implementation

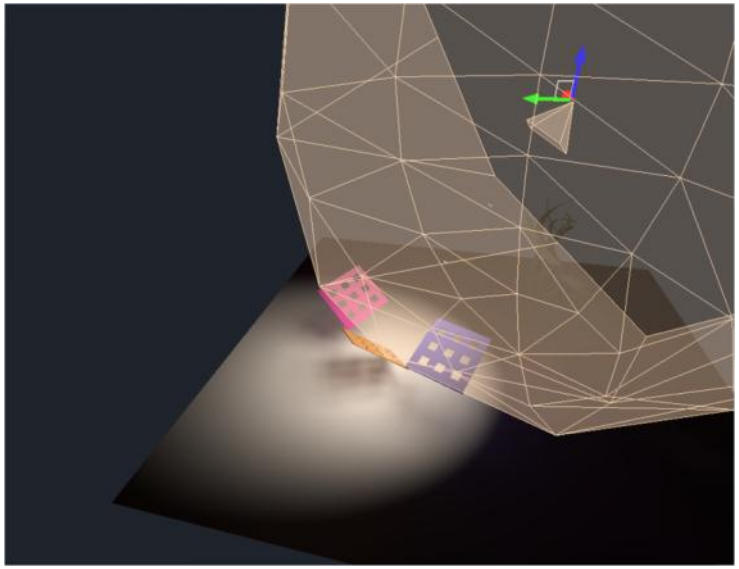
- CUDA
  - Hierarchy generation
  - Generate visibility in screen space
  - Upsample and shade
- Non-trivial
  - Too much code to talk through in detail
  - Dump data to memory was main debugging aid

Results









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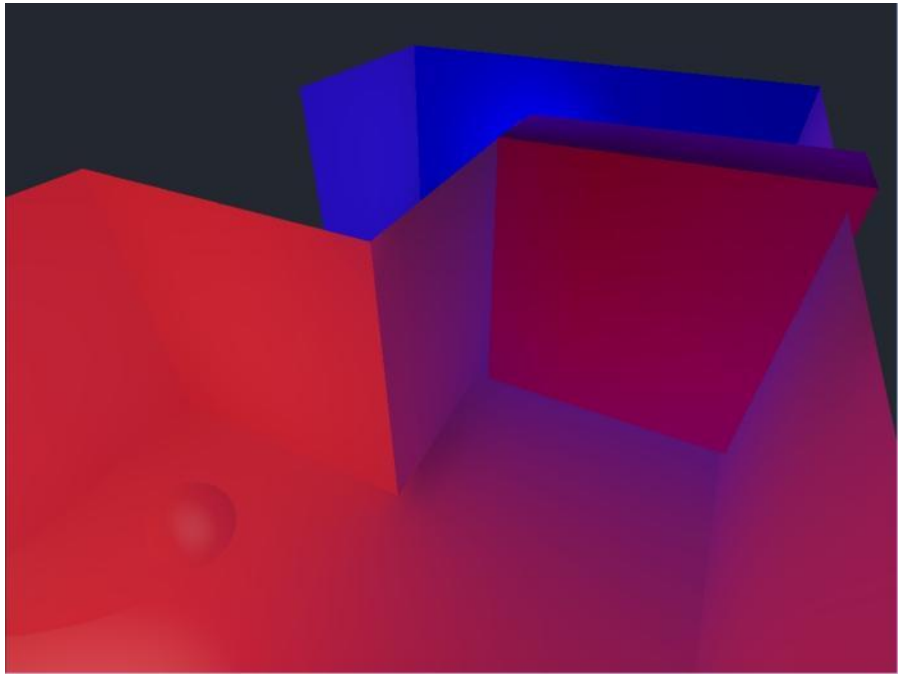
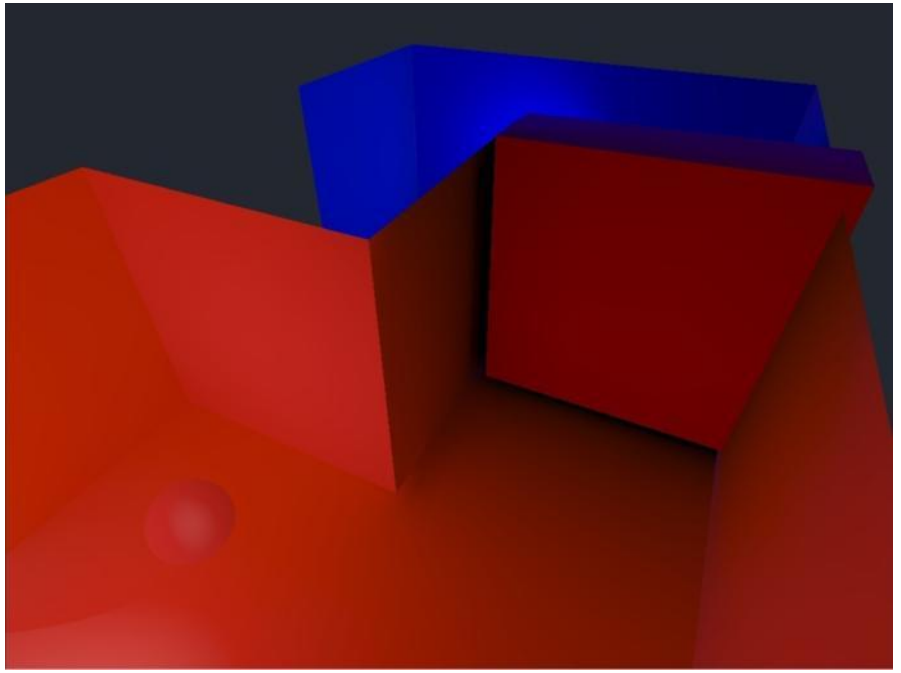
Participating dynamic objects

- Significant new feature for Enlighten
- Dynamic objects contributing to radiosity
- Suitable for large dynamic occluders in a scene
- Not suitable or necessary for small dynamic objects
- Runs extremely well on CUDA!

Participating dynamic objects



Standard Enlighten with blocker as a dynamic object



Enlighten with blocker as a participating dynamic object

Demo

Future concepts

- Beyond lightmaps
  - Greater use of probes
- Iterative refinement
  - Local updates for greater dynamism
- Volumetric effects
  - Smoke, fog, particles interacting with lighting
  - Film style compositing techniques
  - A next gen differentiator

Thank you

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