Which GPU-based Algorithms Cut It?

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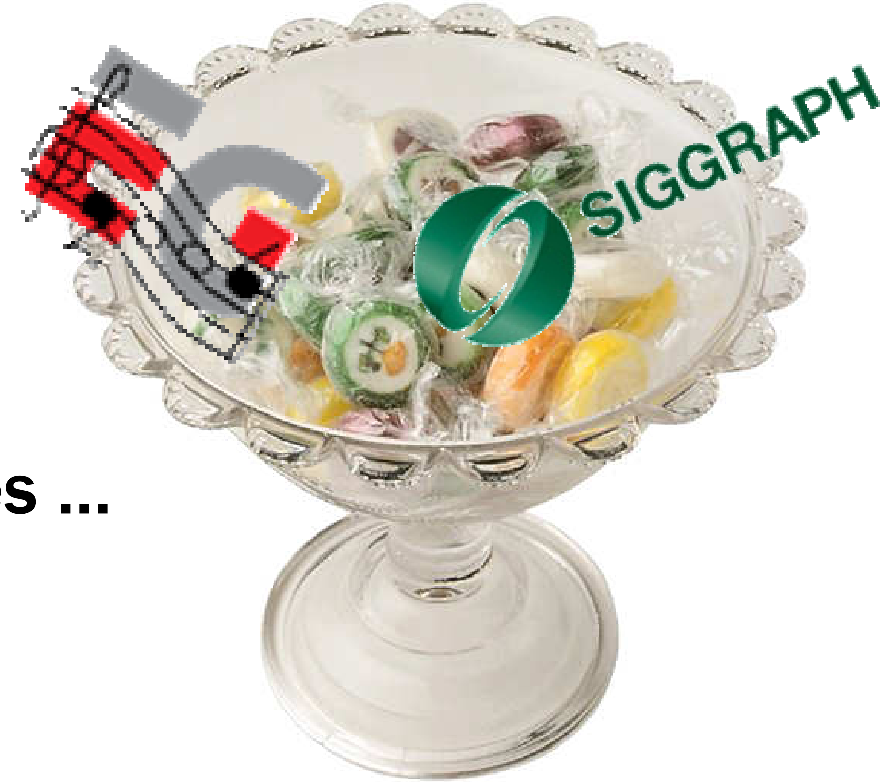
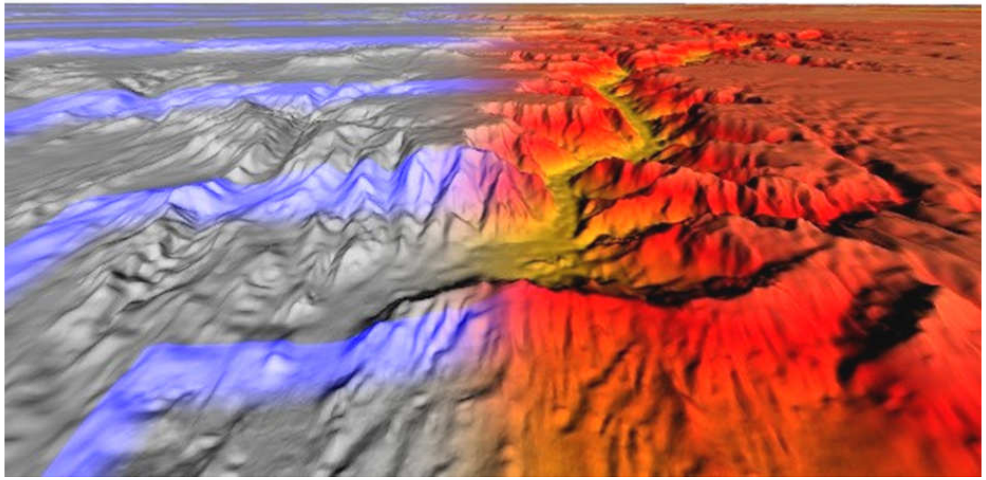
LEIPZIG TUESDAY 22 AUGUST 2006

What GPUs *could* do in games



Some examples ...

What GPUs *could* do in games



Losasso, Hoppe. Geometry clipmaps: Terrain rendering using nested regular grids. SIGGRAPH 2004 and GPU Gems 2

20 G samples at 60 fps, no popping, no hick-ups:

- LOD pyramid; nested grids around the viewer
- Morphing between grids; continuous reloading, decompression

What GPUs *could* do in games

Bunnel. Dynamic ambient occlusion and indirect lighting. GPU Gems 2

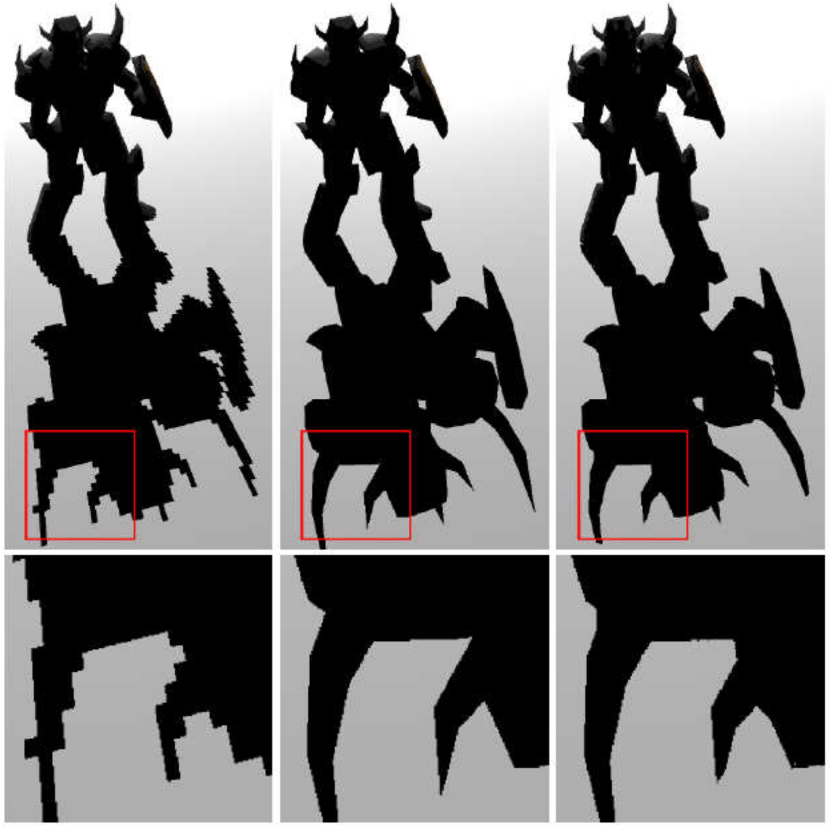
Ambient occlusion:

- **Sum (groups of) polygons as disk-like blockers**
- **Multi-pass to take care of blockers blocking blockers**

What GPUs *could* do in games

Shadows maps
without jaggies:

- Render depth map
  plus shadow silhouettes
- Pixel shader:
  connect the dots

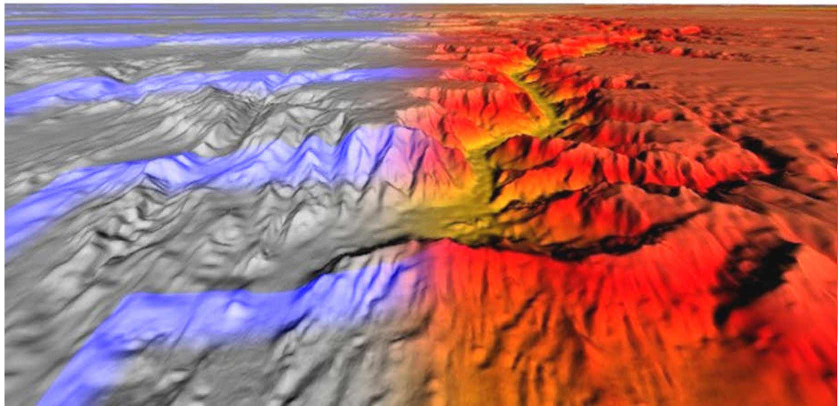


Sen, Cammarano,
Hanrahan. Shadow
silhouette maps.
SIGGRAPH 2003

What GPUs *could* do in games

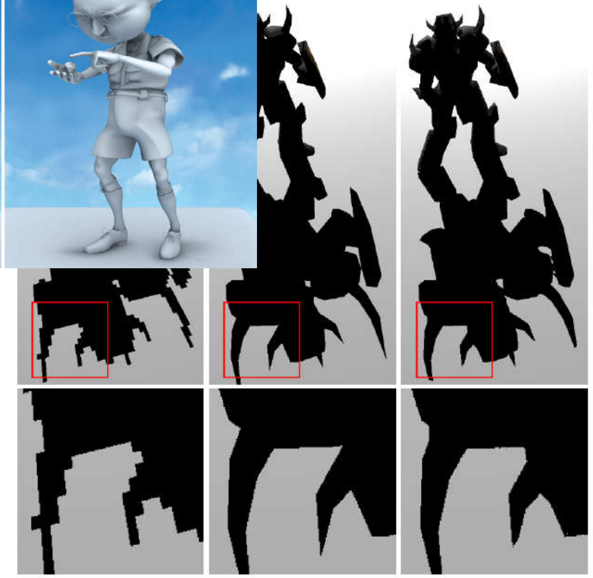
OK, but why don't GPUs actually do this in games?

What GPUs *could* do in games



Completely reorganize assets and render loop?

How to create and manage blockers?



Trade instructions for bandwidth?

Outline

- What's needed?
- What's available?
- So, which algorithms *do* cut it?
- Call to action
- Epilog

What’s needed?

That is:

What are the requirements of game development practice?

What’s needed?

Buzzwords for the press?

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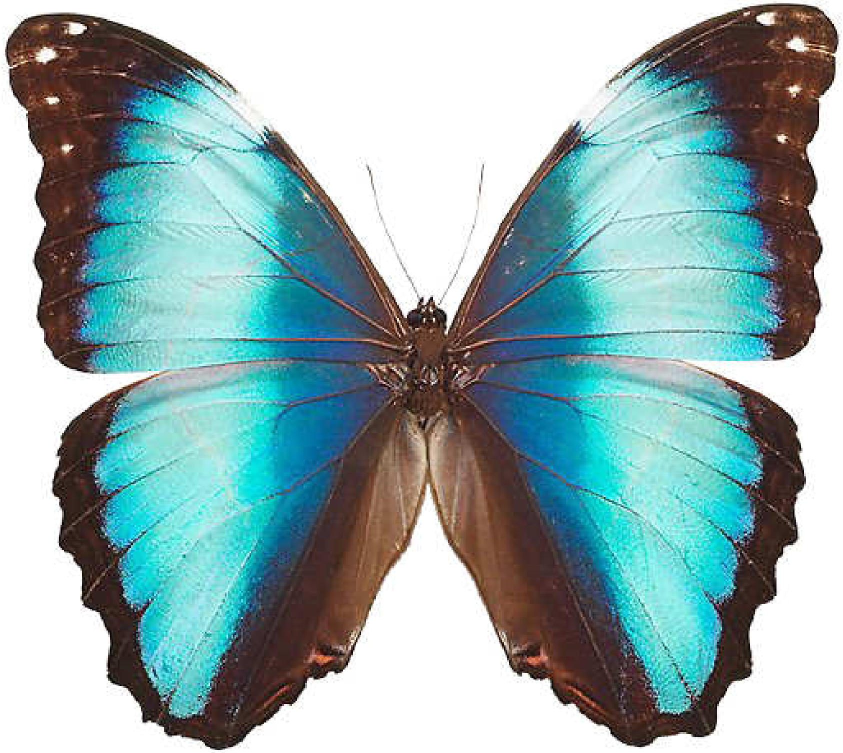
What's needed?

Great results with
lightweight methods!

Which means …



What's needed?

... hard requirements on:

- Timing
  (# of instructions,
  state changes,
  dependent tex reads,
  multithreading, ...)
- Memory
  (textures, vertices,
  off-screen rendering, ...)

What's needed?

Robustness: no tweaking needed, just works

- Unexpected things may happen in a game (shadow acne?)
- Unexpected ideas may crop up during its design (100 NPCs in a swimming pool?)

What's needed?

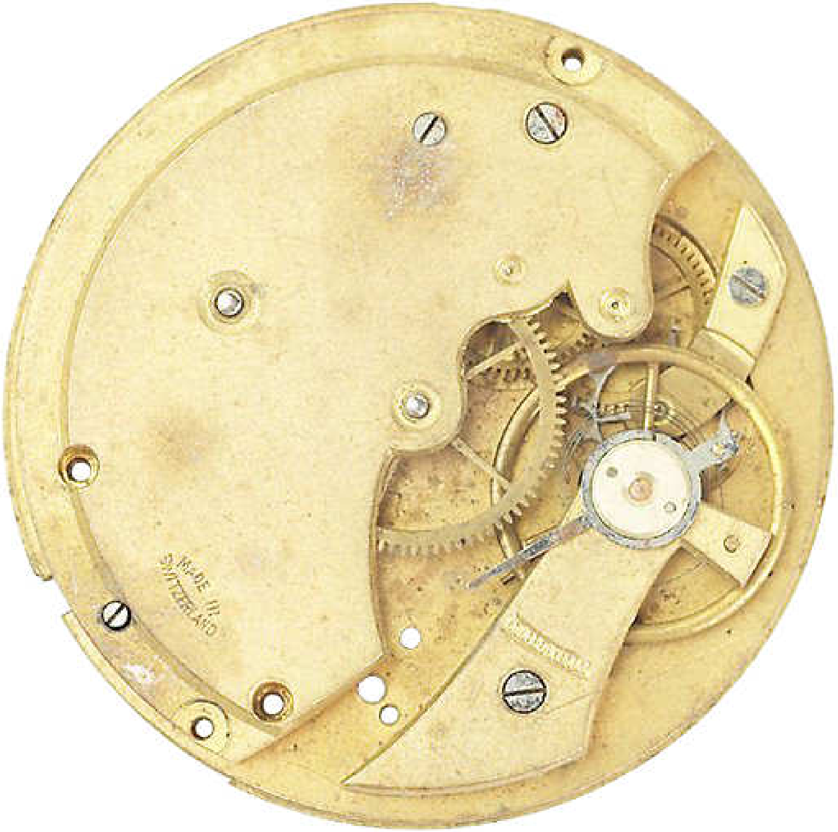
Flexibility: h/w ranges from a shared-memory GPU to a multicore CPU with two graphics cards, XGA

- Scalability (e.g., vertex/pixel workload balance)
- Fallbacks

What's needed?

Integration
with game engine
and/or existing code:

- Shadows?
- Collision, physics?
- Resource Management?
- …



What's needed?

Workflow integration (1):

Reuse of content;
asset management;
integration with DCC
tools

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What's needed?

Workflow integration (2):

- Testing: algorithms, benchmarks, gameplay, … on a range of hardware!

What's needed?

Workflow integration (3):

Division of labor between artists and programmers

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What’s needed?

In short:

- Lightweight processing
- Robustness
- Flexibility
- Run-time integration
- Workflow integration

What’s available?

That is:

What are the results of computer graphics research?

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What's available?

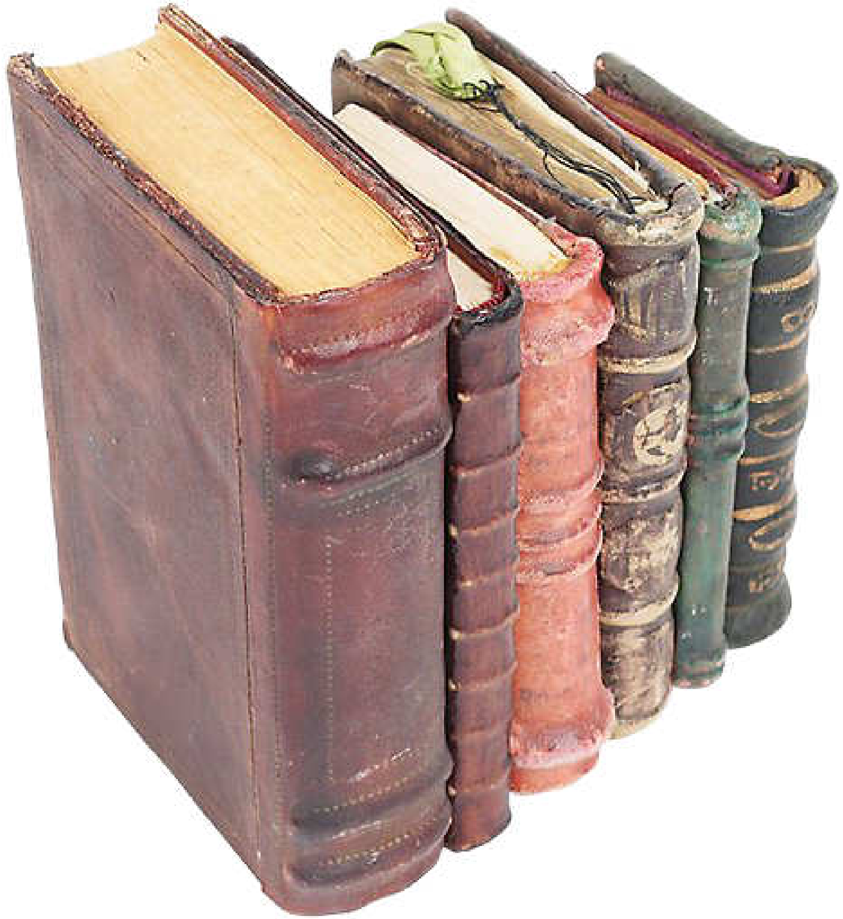
Focus on solitary algorithms:

- One graphical (or non-graphical) effect
- Not 1000 different things to happen at 60 fps
- No integration or systems

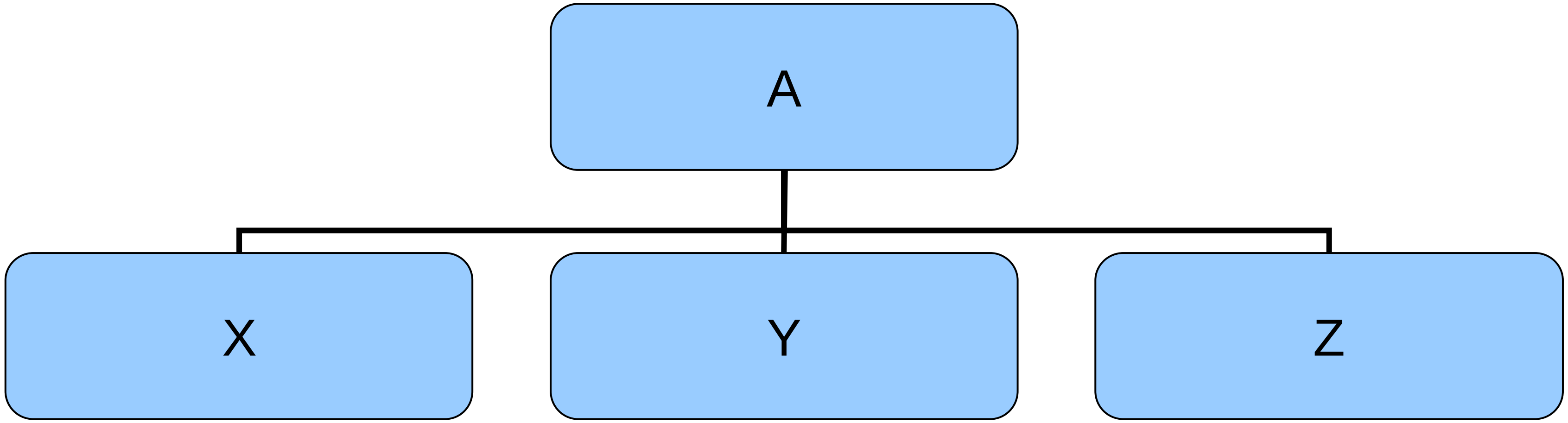
What's available?

Publish or perish:

- Least Publishable Unit? (Owen)
- Applied and inter-disciplinary work disencouraged as "soft"



What's available?



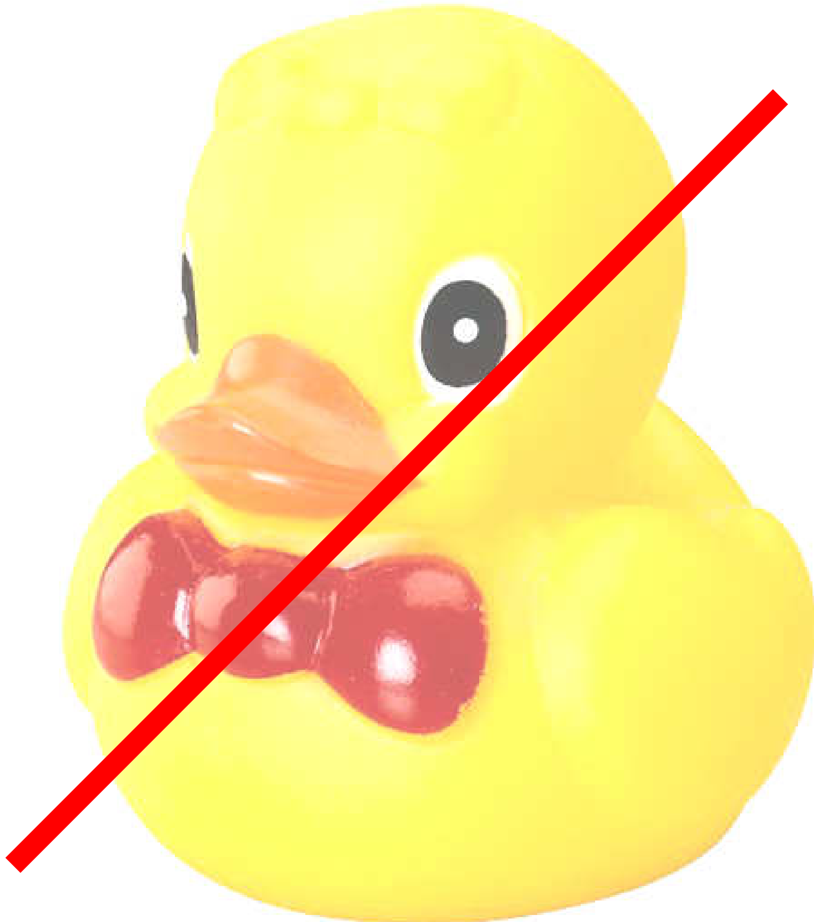
Papers on applications:

- Bunches of block diagrams
- Often sketchy

What's available?

Need to do something arcane and/or sophisticated because all simple things have been done.

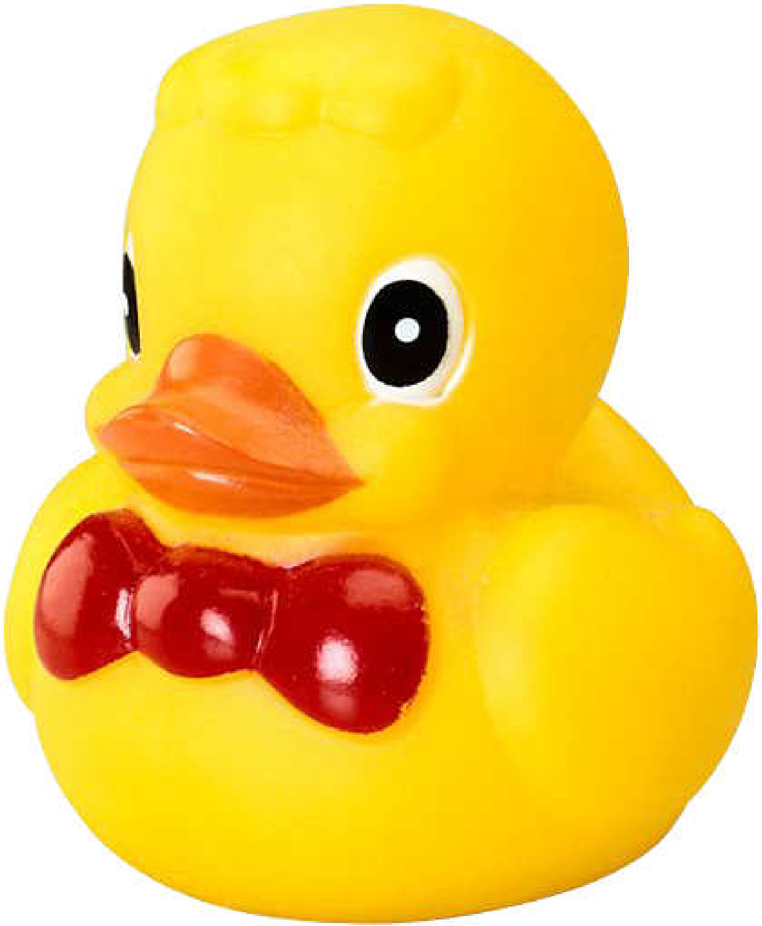
Really?



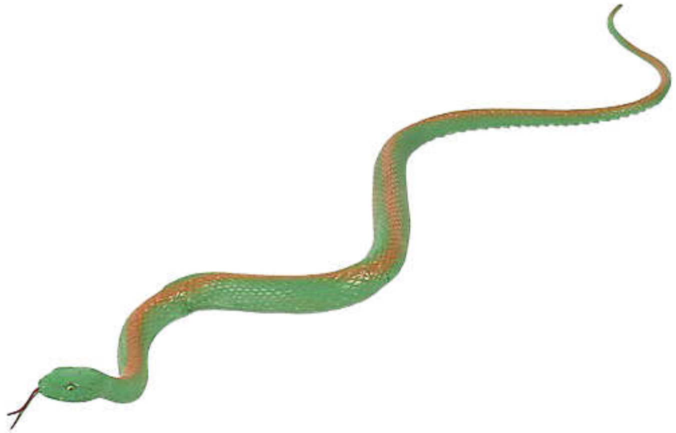
What's available?

Some of those "simple" things:

- Artifact-free noise?
- Sharp textures?
- Volume-preserving soft skinning?
- Carefree shadows?



What's available?



Attempts to make the GPU do tasks it wasn't designed for:

- Is this going to bite back?
- Ugly hack, till the next chip generation comes around? (Testing? Maintaining?)

Wrap-up: Research vs. Practice

No more gems?

;-)

So, which algorithms *do* cut it?

Some examples
with their benefits
and issues:

- Relief mapping
- Mipmapping normal maps
- Bi-level textures
- BRDF-Shop
- PRT

So, which algorithms *do* cut it?

Replace normal maps by virtual geometry:

- Ray casting in the pixel shader
- Convert normal maps to height maps

cf. Parallax Occlusion Mapping etc.

Policarpo, Oliveira. Rendering surface details in games with relief mapping using a minimally invasive approach. ShaderX4

So, which algorithms *do* cut it?

Relief mapping (1):

- Convert normal to height map: automatic step in the build process
- Doom3 demo implementation
- Easily switchable option
- Extensible: multilayer, curved base

So, which algorithms *do* cut it?

Relief mapping (2):

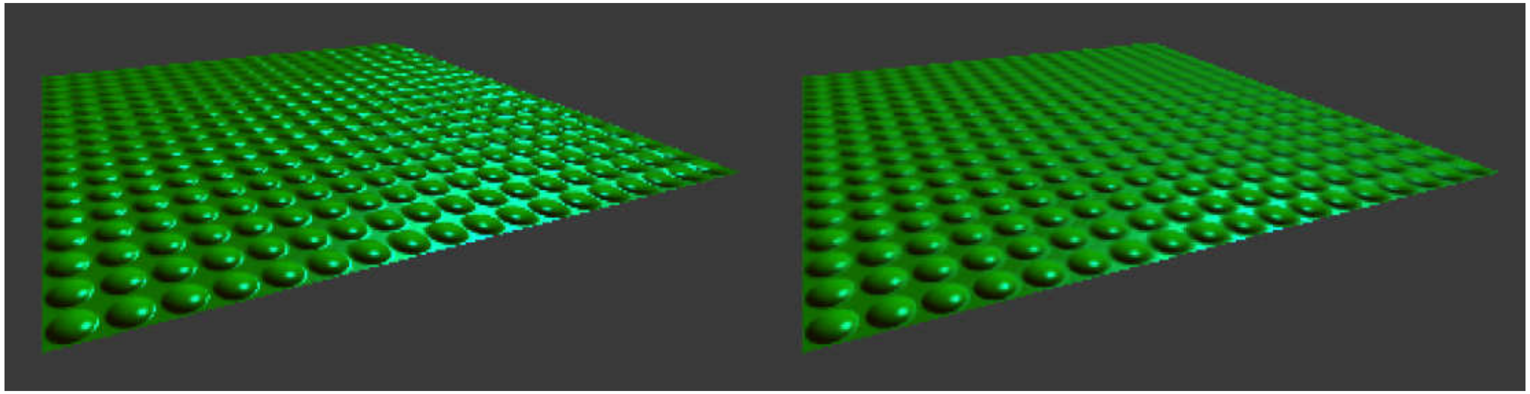
- Best if surface pushed back: expanded models (Keep two versions?)
- Aliasing near, far, at grazing angles
- Computational load:
  approx. 150 PS instructions
- z set for intersections;
  texkill for silhouettes:
  early-z switched off

So, which algorithms *do* cut it?

Relief mapping:

- Lean processing ?
- Robustness ?
- Flexibility ✓
- Run-time integration ✓
- Workflow integration ✓

So, which algorithms *do* cut it?



Toksvig. Mipmapping normal maps. Nvidia online

Better MIP-mapping for normal maps:

- Denormalization of interpolated normals indicates their local divergence
- Model by a Gaussian distribution

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So, which algorithms *do* cut it?

Mipmapping normal maps:

- Fast and simple:
  just one additional 2D texture retrieval
- Issues with locally varying NTB frames
- Helper texture depends on shinyness
  - No local variation?
  - Asset management?

So, which algorithms *do* cut it?

Mipmapping normal maps:

- Lean processing ✓
- Robustness ✓
- Flexibility ✓
- Run-time integration ✓
- Workflow integration ✓

So, which algorithms *do* cut it?

Vector-quality textures without the cost:

- Apply soft thresholding
- Optimize textures offline for best result

Loviscach. Rendering road signs sharply. Game Programming Gems 6

So, which algorithms *do* cut it?

Bi-level textures:

- Jaggies and MIP-mapping handled
- Runs everywhere:
  12 PS instructions, 1 tex read
- Compare to Perfect Hashing (SIGGRAPH 2006): 40 instructions, up to 5 tex reads
- Some manual adjustments with optimizer software required
- Manage hi-res and optimized textures

So, which algorithms *do* cut it?

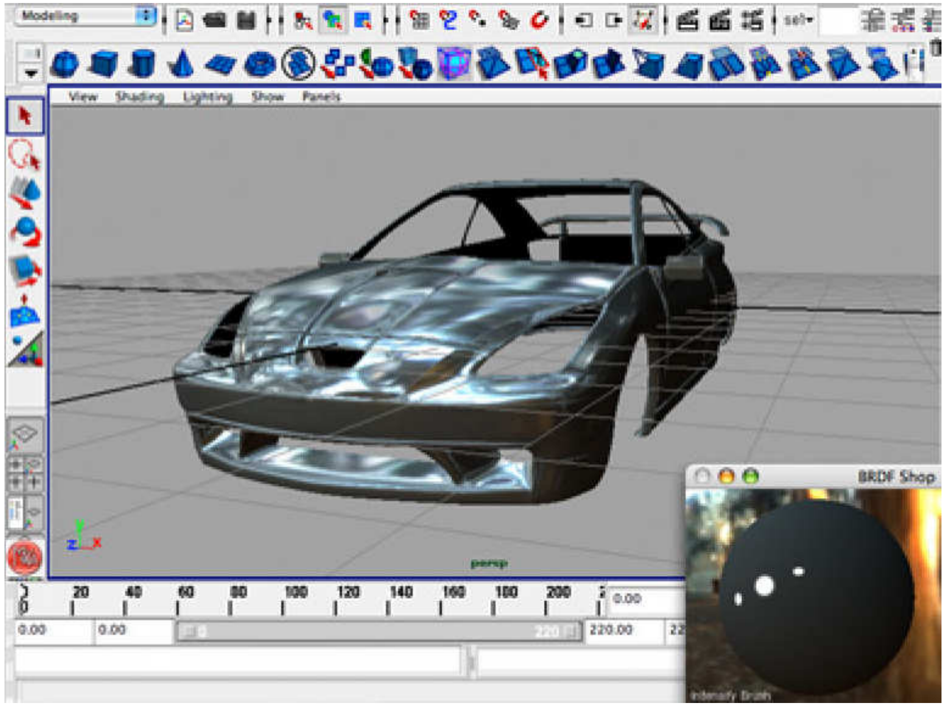
Bi-level textures:

- Lean processing ✓
- Robustness ✓
- Flexibility ✓
- Run-time integration ✓
- Workflow integration ?

So, which algorithms *do* cut it?

Define complex reflective behavior by painting:

- Specialized tools
- Option: restrictions from optical physics



Colbert, Pattanaik and Křivánek. BRDF-Shop: Creating physically correct bidirectional reflectance distribution functions. IEEE CG&A 26, 2005

So, which algorithms *do* cut it?

BRDF-Shop:

- Integrated into Maya, real-time preview
- How to create spatially varying behavior, i.e., textures?
- No run-time component provided?

So, which algorithms *do* cut it?

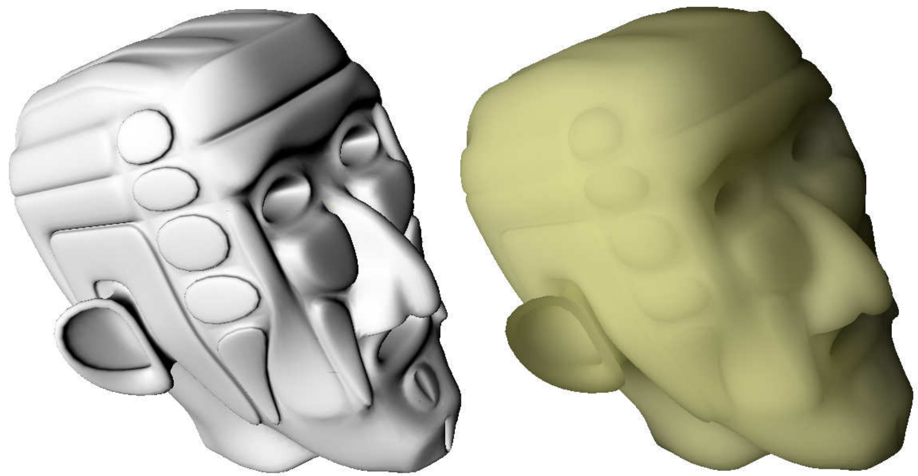
BRDF-Shop:

- Lean processing ?
- Robustness ?
- Flexibility ?
- Run-time integration ✘
- Workflow integration ✓

So, which algorithms *do* cut it?

Encode diffuse light interreflections and SSS into a 3D model

- Spherical harmonics (SH) describe low-frequency variations
- Processing can mostly be done directly in SH base



Sloan, Kautz, Snyder. Precomputed radiance transfer for real-time rendering in dynamic, low-frequency lighting environments. SIGGRAPH 2002

So, which algorithms *do* cut it?

Precomputed Radiance Transfer:

- Precomputation:
  - Software included
  - Adaptive tesselation
- Authoring & runtime software
  - Part of DirectX 9, but what about other platforms?
  - Fallback if performance gets critical?
- About 100 VS instructions;
  need enough triangles
- US patent applications

So, which algorithms *do* cut it?

Precomputed Radiance Transfer:

- Lean processing ✓
- Robustness ✓
- Flexibility ?
- Run-time integration ✓
- Workflow integration ✓

So, which algorithms *do* cut it?

Conclusion:

Even algorithms that look promising have their share of issues.

Call to action

Call to action

For the scientists:

- Think about systems.
  Create better ones?
- Use standard DCC software
  and game engines
- Handle the ugly details
- Publish “Lessons learned,”
  i.e., negative results

Call to action

For the developers:

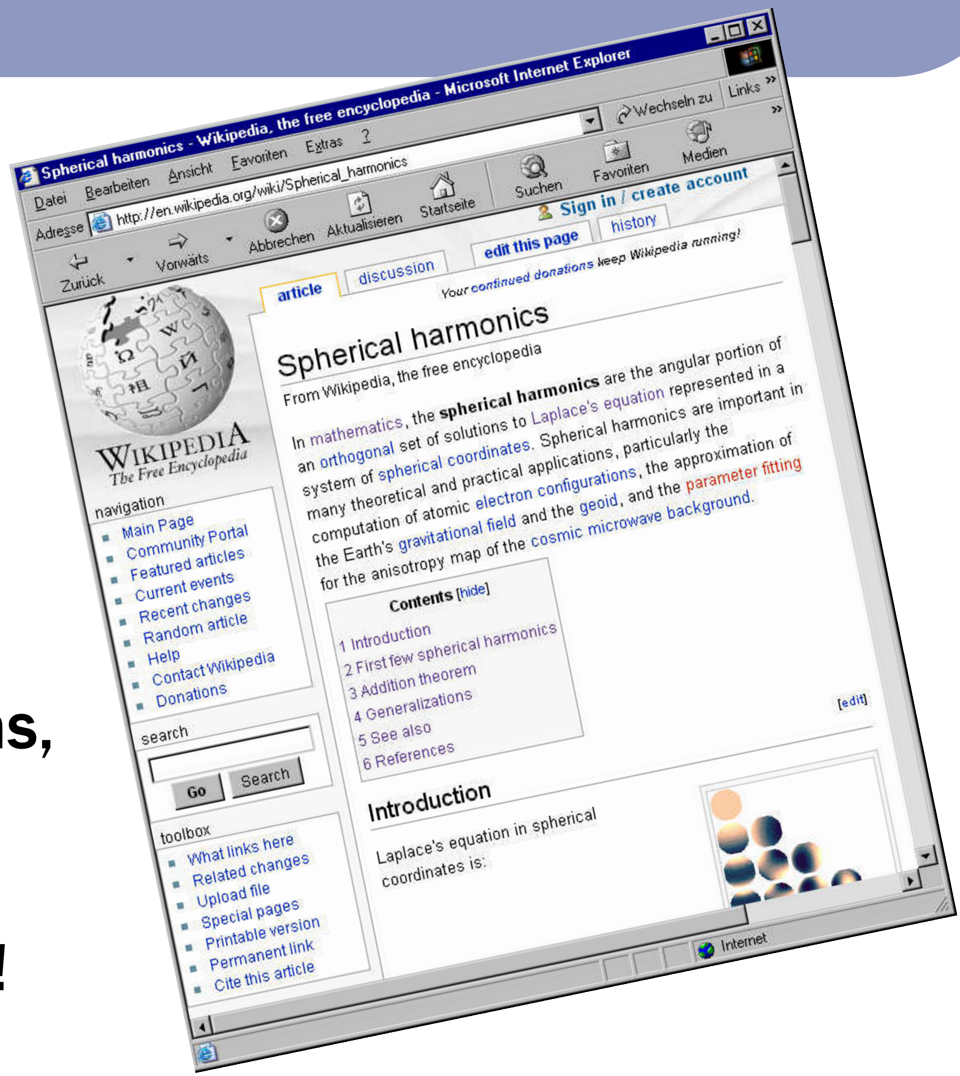
- What are
  the day-to-day issues
  of game production?
- How would you like
  to create games
  for tomorrow's platforms?

Let the researchers know!

Call to action

For the developers (cont'd):

- Efficient apps of GPUs need more than geometry: advanced linear algebra, PCA, harmonic functions, …
- This is where researchers shine!



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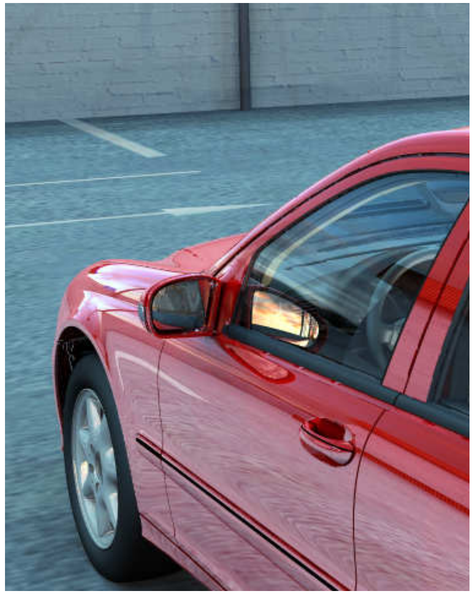
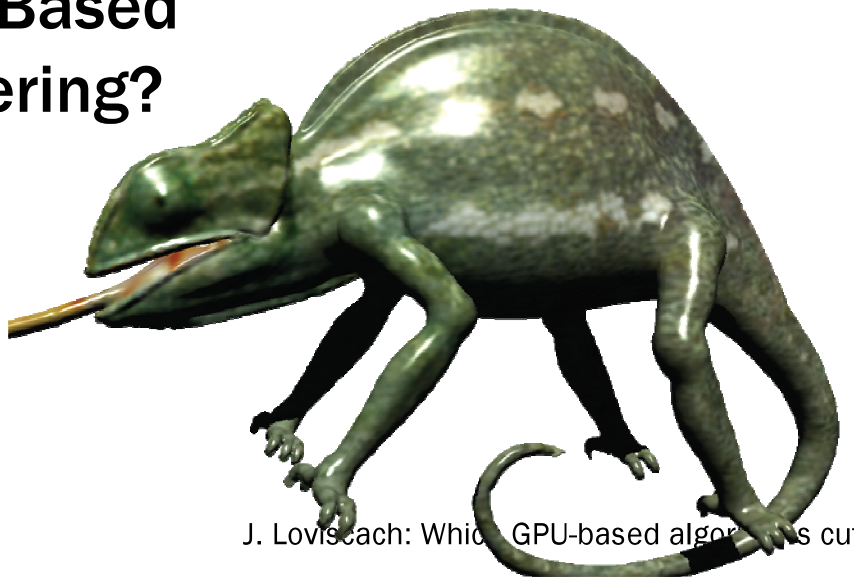
Epilog

GPU programming:
To where from here?

- Z buffer
  till the end of days?
- Ray tracing?
- Point-Based
  Rendering?

Wald et al. A ray tracing based virtual reality framework for industrial design. IEEE Symposium on Interactive Ray Tracing 2006





Botsch, Hornung, Zwicker, Kobbelt. High quality surface splatting on today's GPUs. EG Symp. on Point-Based Graphics 2005

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Epilog

- How to cope
  with radical changes?
- Long-term investment:
  start abstracting today
  to save your code
  and content
- Today's hack may
  be tomorrow's
  built-in feature

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Thanks for your attention.

Questions?

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