WebGL pathtracing

Challenges and benchmark

Thomas Kjeldsen and Peter Trier Mikkelsen

Alexandra Instituttet

thomas.kjeldsen@alexandra.dk

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Outline

- Alexandra Instituttet
- Motivation
- Demo
- Implementation
- Benchmark

Alexandra Instituttet - Mission

- Not-for-profit GTS institute within IT
- Add value to the Danish Industry
- From research to applications in industry

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- Computer Graphics Lab
  - Interactive visualization (fast, high quality)
  - Accurate simulation of materials $\rightarrow$ photo realistic images
  - Acceleration (using GPUs)
  - Solving numerical problems
  - Physical simulations (fluids, soft bodies)

Motivation - part 1

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- Interactive, realistic rendering in a web browser

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- Interactive, realistic rendering in a web browser
    - E.g. realistic preview of customizable products in a web store
- Raytracing is computationally expensive (not feasible to implement in javascript)
- WebGL is a new standard that allows us to access the power of the graphics card

Motivation - part 2

Motivation

- Have you ever experienced this situation?

Motivation

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- You receive an email from you friend

Hey, click on this link to view some cool interactive 3D graphics. Link

Motivation

- Or, Flash, Unity, java, etc.

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- Or, Flash, Unity, java, etc.
- WebGL is natively supported by modern browsers

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Demo

Demo 1
Demo 2

Implementation

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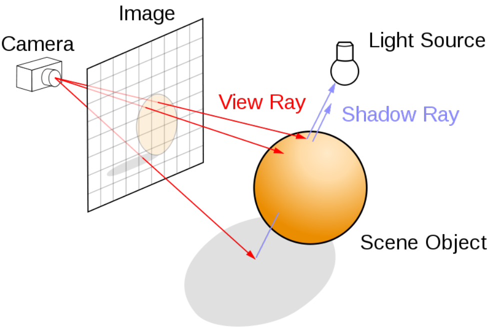
Implementation

- WebGL is nearly equivalent to OpenGL ES 2.0
- Programmable pipeline allows us to do complex calculations per pixel
- In our case: Execute a ray tracing program for each pixel on the screen



Source: http://en.wikipedia.org/wiki/File:Ray_trace_diagram.svg

Implementation

Simplified pathtracing algorithm

- Upload triangle data to the graphics memory using textures

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Simplified pathtracing algorithm

- Upload triangle data to the graphics memory using textures
- Fragment shader for each pixel

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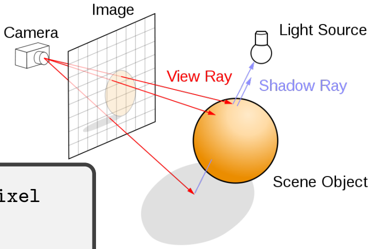
Launch a ray from the camera through the pixel
{
  Intersect the ray with all triangles

  Record the color at the closest hit point

  Launch a secondary ray from the hit point

  Repeat until the ray hits a light source
}
Pixel color = BRDF * cos / pdf * light color
```



Challenge 1 - long shaders fail to compile

- Some shader compilers unroll loops - in particular on Windows (ANGLE OpenGL to DirectX translation)

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- Inner loop over ray-triangle intersections ~ 1000
- Outer loop over secondary bounces ~ 5
- Our shader fails to compile on Windows!

Challenge 1 - long shaders fail to compile

- Solution: Trace each secondary bounce in a separate pass

Challenge 1 - long shaders fail to compile

- Solution: Trace each secondary bounce in a separate pass
- We need to store the hit record between each pass
  - Hit position (3 floats)
  - Ray direction (3 floats)
  - Hit material (1 int)
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- Unfortunately WebGL only supports a single render target, i.e., we can only transfer four floats between two passes
- We must encode the hit record to fit in just four floats

Challenge 2 - acceleration structure

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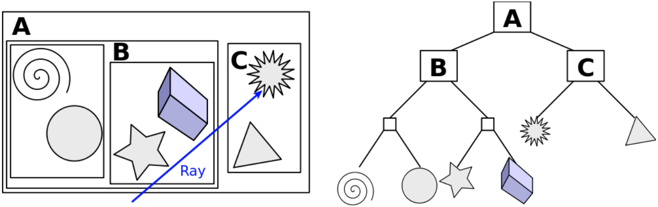
- Linear scaling with number of triangles
- Use an acceleration structure

Challenge 2 - acceleration structure

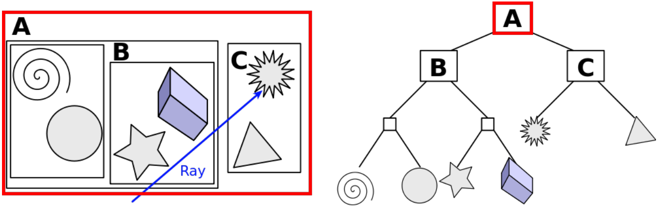
Bounding volume hierachy



Source: http://en.wikipedia.org/wiki/File:Example_of_bounding_volume_hierarchy.svg

Challenge 2 - acceleration structure

Bounding volume hierachy



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Traversal:

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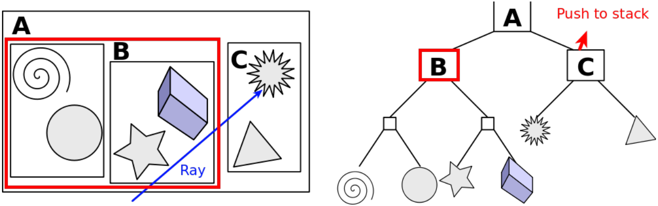
Challenge 2 - acceleration structure

Bounding volume hierachy



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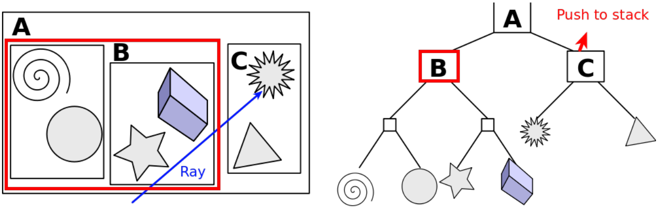
  - Descent through B and push C on a stack

Challenge 2 - acceleration structure

Bounding volume hierachy



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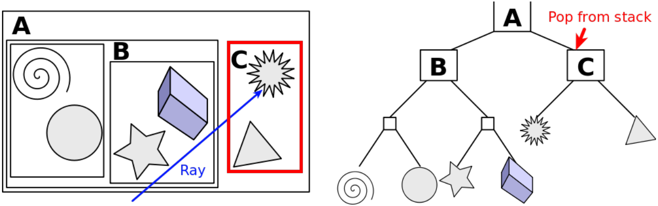

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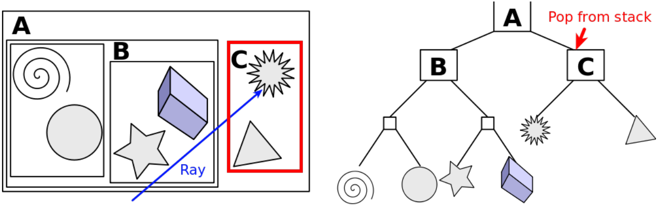

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Challenge 2 - acceleration structure

Bounding volume hierachy - tree traversal

- Shaders are suited for parallel execution of simple tasks

Challenge 2 - acceleration structure

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- Fixed-size stack can be implemented in recent versions of the OpenGL shading language - but not in WebGL

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Challenge 2 - acceleration structure

Bounding volume hierachy - tree traversal

- Shaders are suited for parallel execution of simple tasks
- No support for dynamic memory allocation needed for a stack
- Fixed-size stack can be implemented in recent versions of the OpenGL shading language - but not in WebGL
- We have implemented two stackless BVH traversal algorithms

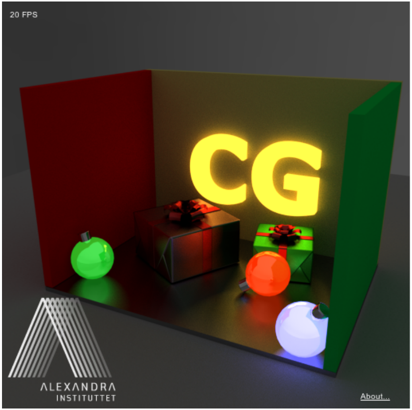
  Laine HPG 2010: Restart Trail for Stackless BVH traversal

  Hapala SCCG 2011: Efficient Stack-less BVH Traversal for Ray Tracing

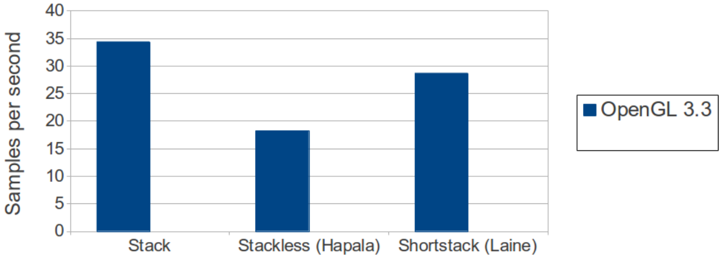
Benchmark

Benchmark setup

- Nvidia GeForce 470GTX
- Xeon E5620 Quad, 2.4 GHz
- Firefox 21 on linux
- 512px x 512px
- 4 secondary bounces



Benchmark - traversal



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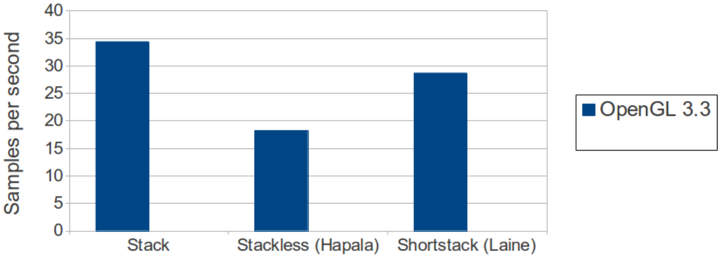
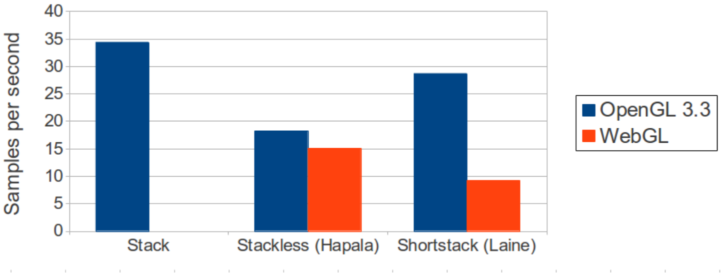


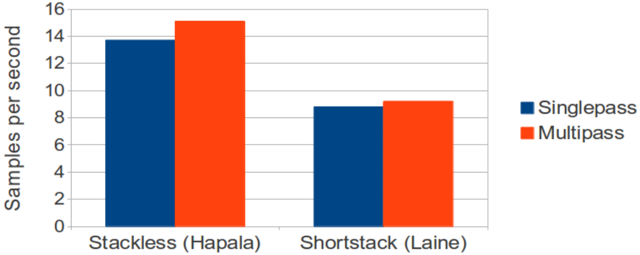
- Stackless traversal revisits internal nodes

Benchmark - traversal



- Stackless traversal revisits internal nodes
- Shortstack algorithm depends on efficient bitwise operations

Benchmark - multiple passes



Outlook

- Looking for real-world applications

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- Next version of WebGL will probably be based on OpenGL ES 3.0, hopefully enables support for
  - Bitwise operations (efficient shortstack BVH traversal)
  - Multiple render targets (save hit record between passes)
  - Full array support (stack implementation)

Thank you

- Visit our blog:
  http://cg.alexandra.dk
- Demos:
  http://cg.alexandra.dk/files/pathtracer/?scene=XmasScene
  http://cg.alexandra.dk/files/pathtracer/?scene=motorcycle

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