These notes were taken from a variety of sources including text book, Wikipedia, various Maya references, and SIGGRAPH articles

Video Game Technologies

6931: MSc in Computer Science and Engineering

Chap. 10 — Shadowing

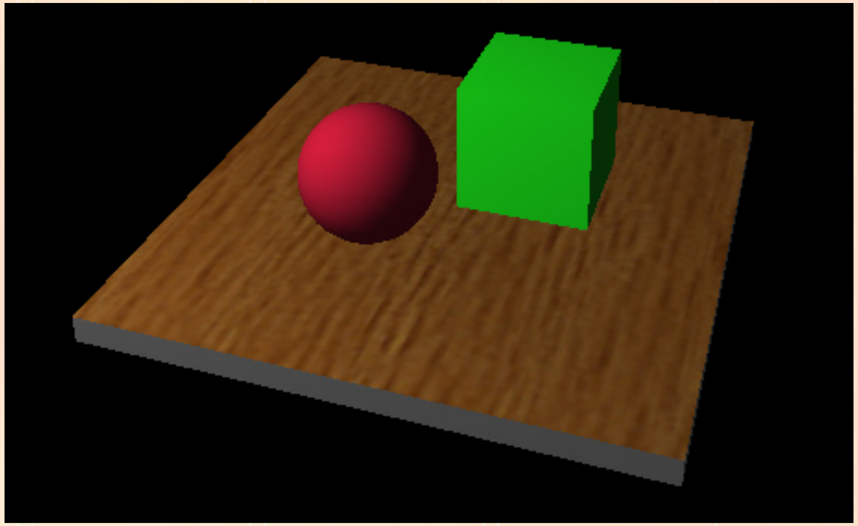
Shadowing

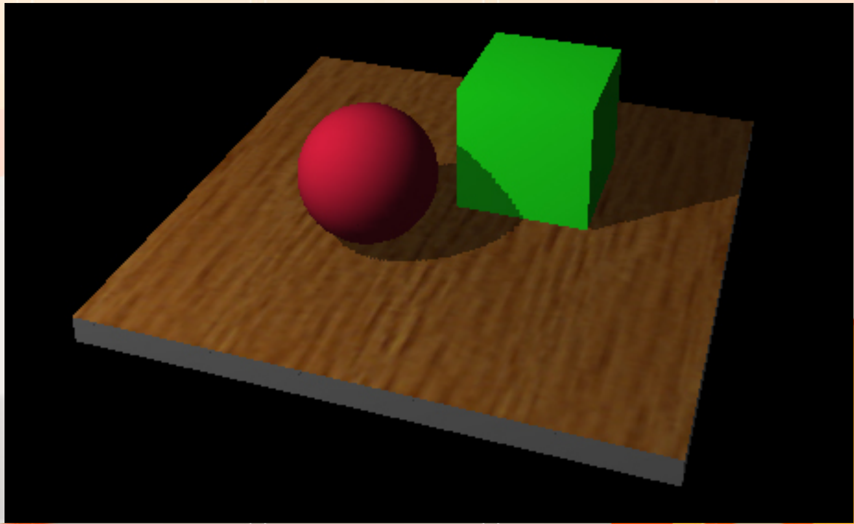
Overview

- Motivation.
- Classification of shadowing algorithms: geometry-based and image-based.
- Pros and cons of geometry-based shadowing algorithms.
- Pros and cons of image-based shadowing algorithms.
- Shadow mapping algorithm.
- Shadow mapping issues.
- Final remarks.

Motivation

- Why are shadows important?
  - Add a sense of presence and volume to a scene
  - Important visual cues
  - Make for interesting gameplay mechanics
  - Adds to realism (caveats?)
  - Players expect dynamic lighting
    - Shadows play a major role
- How many different ways are there to shadow?
  - In a word: lots





(Screenshots taken from "shadowcast.exe" by Mark J. Kilgard, NVIDIA)

Shadowing algorithms

- Geometry Based
  - Projected Shadows
    - Geometry collapse using "Shadow Matrix"
  - Shadow Volumes
    - Regular volumes
    - Z-fail / "Carmack's Reverse"
    - GPU-generated
  - Both cases ~O(n) in terms of scene complexity

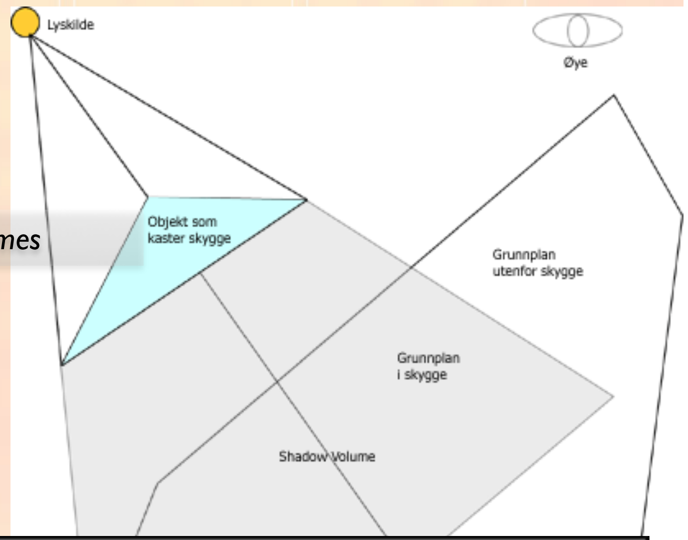
- Image Based
  - Shadow Mapping
    - Depth-based shadowing system
    - Many variants: PSM, TSM, LiSPSM, PSSM, CSM, VSM, DPSM, etc.
    - Relatively O(1) in terms of geometric scene complexity
  - Forward Shadow Mapping

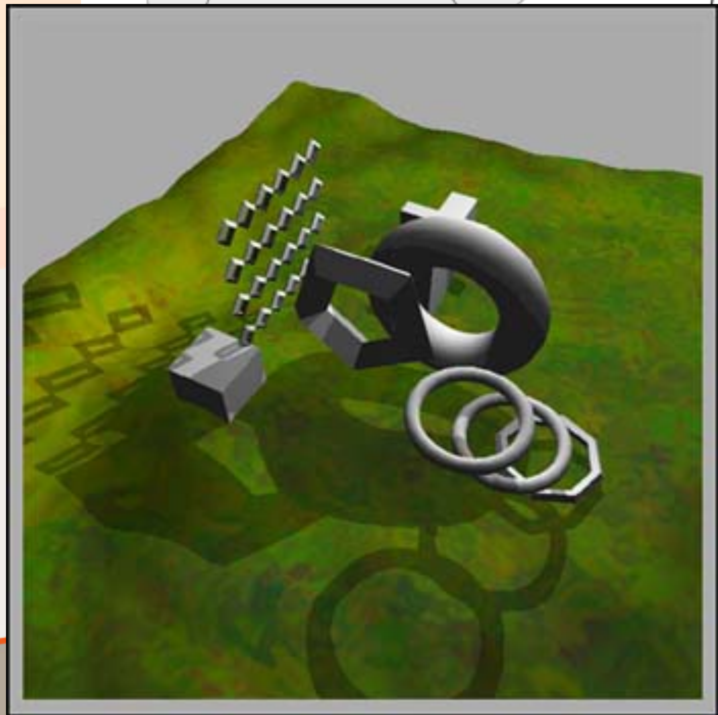
Images courtesy of Østfold University College, Norway and NVIDIA Corporation

Geometry-based shadowing algorithms

- **Pros**
  - Sharp, crisp shadows
  - Easy to compute
    - If it's visible on-screen, you already have the data to shadow it
  - Easily extendable to the vertex shader
    - Speed benefits through pipeline-integration
- **Cons**
  - Shadow complexity is O(n), n = # edges
    - Means speed α complexity^{-1}
    - Fine balance between object count and edge resolution
  - Requires image-space modification or ugly jitter for soft-shadows
  - No support for alpha-blended textures without extreme trickery
    - We're talking leprechaun-level, here…

Shadow volumes





Tobias Martin and Tiow-Seng Tan. Anti-aliasing and Continuity with Trapezoidal Shadow Maps. In the Proceedings of Eurographics Symposium on Rendering, 21-23 June 2004, Norrköping, Sweden, pp. 153-160, 2004.

Image-based shadowing algorithms

- **Pros**
  - Shadow complexity α scene complexity!!
    - Means cube equally expensive as Marcus Fenix ™ (sorta…)
  - Gives shadowed alpha for free
  - Soft shadows feasible in real-time
  - Self-shadowing is free
- **Cons**
  - Inherently aliased / artifact'd
    - Aliasing from texture resolution and light projection settings
    - Artifacts from limitations of texture projection
    - Both are mitigated through technique variations
  - Memory intensive
    - Memory consumption α shadow quality
  - No unified approach
    - Different techniques for different situations…

http://www.comp.nus.edu.sg/~tants/tsm.html

This presentation will focus on ***shadow mapping***, its theory, implementation and variants.

- On modern hardware, shadow mapping pros far outweigh cons:
  - Scenes in games are growing in complexity
  - Vertex-bound techniques will cause even more problems as time progresses
  - Independent of model / vertex data architecture

L. Williams. Casting curved shadows on curved surfaces. In Proceedings of SIGGRAPH 1978, 270–274, 1978.

What is shadow mapping?

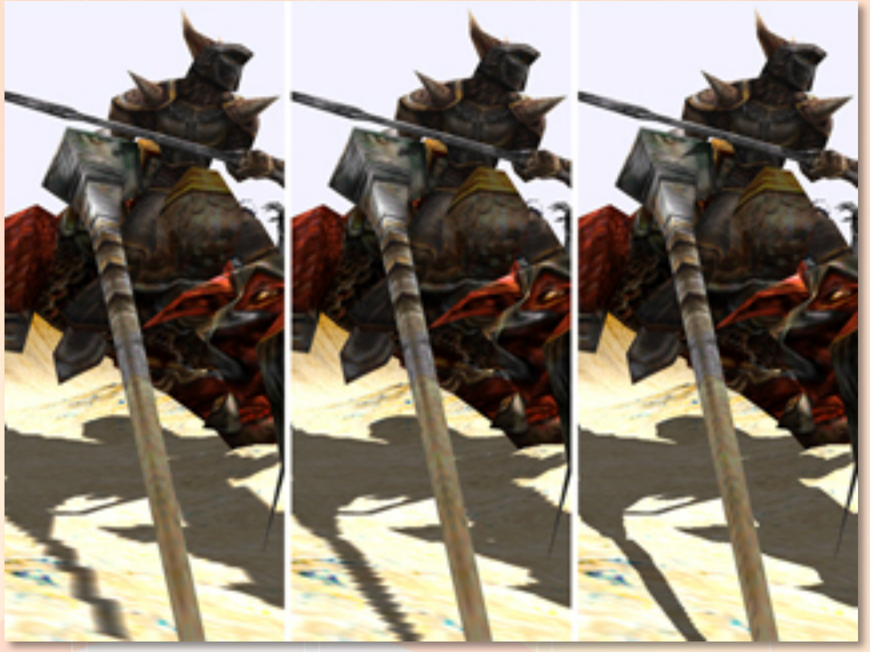
- ***History***. Introduced in 1978 and is now widely used in real time graphics.
- ***Motivation***. Adds a level of realism to a scene with a two pass algorithm.
- ***Algorithm overview***:
  - First pass renders a scene from the light's point of view storing the depth of each pixel into an image.
  - Second pass renders a scene from the eye's point of view including shadow determination for each pixel.
  - If the depth of a pixel is greater than the stored depth it is in the shadow, otherwise it is visible.
- ***Principal issue***:
  - Introduces aliasing, or the effect of 'different continuous signals to become indistinguishable when sampled'.
- ***Solutions***:
  - There are multiple types of maps that deal with the issue of aliasing, quality, and render speed:
    - Perspective, adaptive, deep, trapezoidal, and variance opacity.

Shadow mapping algorithm

- It is a two-pass process.
- 1st Pass: Generating the shadow map
  - Render from light's point of view
    - Any object that can be seen must be lit
    - Store the depth value of every element
- 2nd Pass: Shadowing the scene
  - Render the scene as normal
    - Take the position of every vertex
      - Transform into light-space coordinates
      - Retrieve the point as it is seen from the point of view of the light (depth map)
    - Depth-compare with light-view map
      - If depth value of surface is further away, it must be behind an occluder and shadowed (z-fail test)

Shadow mapping issues

- Resolution/aliasing issue:
  - As light moves further away from eye/viewpoint aliases are produced from low resolution maps.
- Polygon offset issue:
  - Surface distortion effects caused by inaccurate depth buffer values.
- Continuity issue:
  - Significant change in shadow map quality from one frame to another.
  - Results In shadow flickering.



http://www.comp.nus.edu.sg/~tants/tsm.html

Further reading

- BRABEC, S., ANNEN T., AND SEIDEL, H. 2002. Practical Shadow Mapping. Journal of Graphics Tools 7(4), 9–18.
- CROW, F. C. 1977. Shadow Algorithms for Computer Graphics. In Proceedings of SIGGRAPH 1977, 242–248.
- STAMMINGER, M., AND DRETTAKIS, G. 2002. Perspective Shadow Maps.
- WILLIAMS, L. 1978. Casting curved shadows on curved surfaces. In Proceedings of SIGGRAPH 1978, 270–274.
- WOO, A., POULIN, P., AND FOURNIER, A. 1990. A survey of shadow algorithms. IEEE Computer Graphics and Applications, 10(6), 13–32.

Summary

- Motivation.
- Classification of shadowing algorithms: geometry-based and image-based.
- Pros and cons of geometry-based shadowing algorithms.
- Pros and cons of image-based shadowing algorithms.
- Shadow mapping algorithm.
- Shadow mapping issues.
- Final remarks.