CSE 167: Introduction to Computer Graphics Lecture #15: Procedural Modeling

Jürgen P. Schulze, Ph.D.
University of California, San Diego
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Announcements

- Final project outline due November 19
- Second midterm exam: Tuesday November 23rd during lecture hours (2-3:20pm)
- Phi will do late grading for assignment 6 tomorrow (Friday): 2-3pm
- Please check Gradesource for accuracy. Homework assignments 1-6 and midterm should be complete.

Final Project

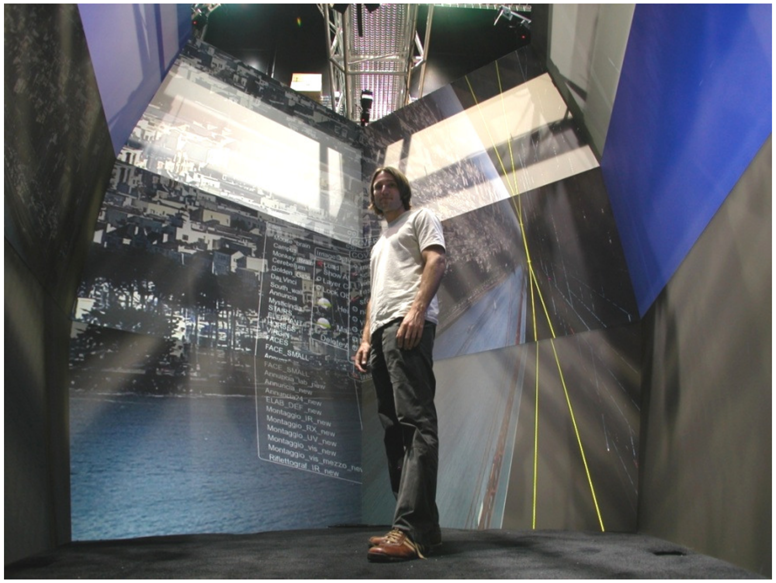
- Problem description is on-line
- Must be done in teams of two or three
- Application design description (min. 300 words) due Friday, November 19 at 4pm.
  Email to me: `jschulze@ucsd.edu`
- Project due to be presented on
  Friday, Dec 3rd, between 2 and 4pm
- No late submissions accepted

StarCAVE Tour

- Location: Atkinson Hall, 1st floor
- 18 Dell XPS PCs with Quad Core Intel CPUs
- CentOS 5.3 Linux
- Dual Nvidia Quadro 5600 graphics cards per node
- 34 JVC HD2k projectors (1920x1080 pixels): ~34 megapixels per eye
- Passive stereo with circular polarization filters
- 15 screens, ~8 x 4 feet each
- Floor projection
- Optical, wireless tracking system
- Software: COVISE
- Programming Language: C++

Tour Date:
- Friday, Nov 19, 4:00-5:00pm

Location:
Immersive Visualization Laboratory
1st floor Atkinson Hall
Turn right at main entrance



Lecture Overview

- Procedural Modeling
  - Concepts
  - Algorithms
- Shadow Volumes

Modeling

- Creating 3D objects/scenes and defining their appearance (texture, etc.)
- So far we created
  - Triangle meshes
  - Bezier patches
- Interactive modeling
  - Place vertices, control points manually
- For realistic scenes, need extremely complex models containing millions or billions of primitives
- Modeling everything manually is extremely tedious

Alternatives

- Data-driven modeling
  - Scan model geometry from real world examples
  - Use laser scanners or similar devices
  - Use photographs as textures
  - Examples
    - http://www-graphics.stanford.edu/data/3Dscanrep/ http://www.tsi.enst.fr/3dmodels/
    - .ply file format reader http://w3.impa.br/~diego/software/rply/
- Procedural modeling
  - Construct 3D models and textures with algorithms

Photograph Rendering

[Levoy et al.]

Procedural Modeling

- Wide variety of techniques for algorithmic model creation
- Used to create models too complex (or tedious) for a person to build
  - Terrain, clouds
  - Plants, ecosystems
  - Buildings, cities

[Deussen et al.]

- Usually defined by a small set of data, or rules, that describes the overall properties of the model
  - Tree defined by branching properties and leaf shapes
- Model is constructed by an algorithm
  - Often includes randomness to add variety
  - E.g., a single tree pattern can be used to model an entire forest

Randomness

- Use some sort of randomness to make models more interesting, natural, less uniform, clean
- *Pseudorandom* number generation algorithms
  - Produce a sequence of (apparently) random numbers based on some initial seed value
- Pseudorandom sequences are repeatable, as one can always reset the sequence
  - E.g., if a tree is built using pseudorandom numbers, then the entire tree can be rebuilt by resetting the seed
  - If the seed is set to a different value, a different sequence of numbers will be generated, resulting in a (slightly) different tree

Recursion

- Repeatedly apply the same operation (set of operations) to an object
- Generate objects that are self-similar: fractals
  - Objects that look the same when viewed at different scales
- For example, the shape of a coastline may appear as a jagged line on a map
  - As we zoom in, we see that there is more and more detail at finer scales
  - We always see a jagged line no matter how close we look at the coastline

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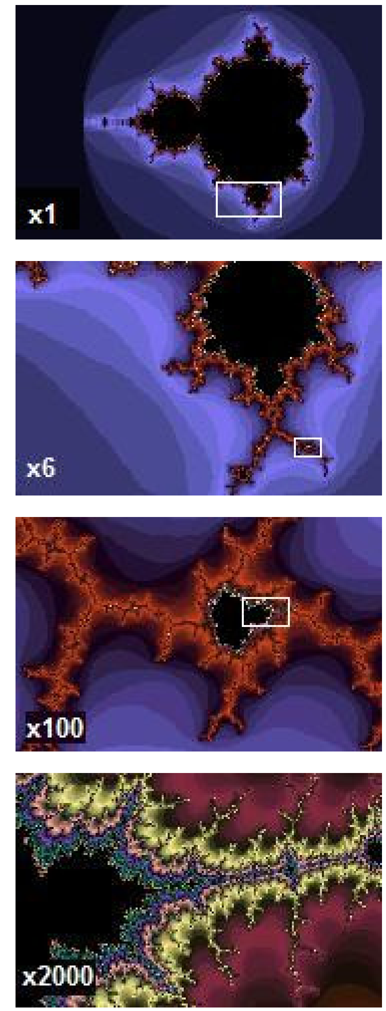
Height Fields

- Landscapes are often constructed as *height fields*
- Regular grid on the ground plane
- Store a height value at each point
- Can store large terrain in memory
  - No need to store all grid coordinates: inherent connectivity
- Shape terrain by operations that modify the height at each grid point
- Can generate height from grey scale values
  - Allows using image processing tools to create terrain height
  - → Extra credit in Homework Assignment #2

Fractals

- Fractal:
  Fragmented geometric shape that can be split into parts, each of which is (at least approximately) a reduced-size copy of the whole
- Self-similarity

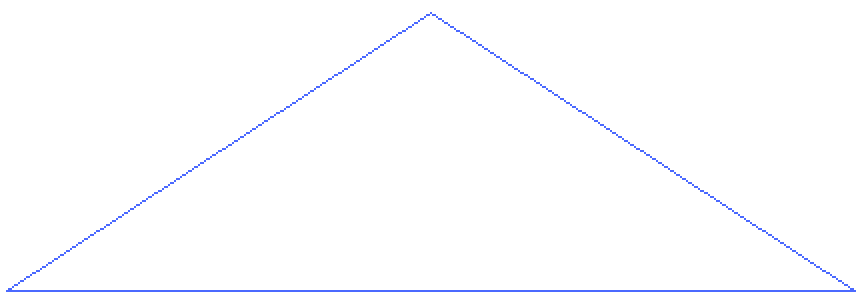
- Demo: Aros Fractals
  http://www.arosmagic.com/redblue/arosmagic.com/fractals/



From Wikipedia

Fractal Landscapes

- Random midpoint displacement algorithm
  - Recursively subdivide triangles
  - Displace edge midpoints with fractal formula
  - Reduce size of displacement as triangles get smaller
  - Similar for quadrilaterals



[Wikipedia]

Fractal Landscapes

- Add textures, material properties; use nice rendering algorithm
- Example: Terragen Classic (free software) http://www.planetside.co.uk/terragen/

[http://www.planetside.co.uk/gallery/f/tg09]

L-Systems

- Developed by biologist Aristid Lindenmayer in 1968 to study growth patterns of algae
- Defined by grammar

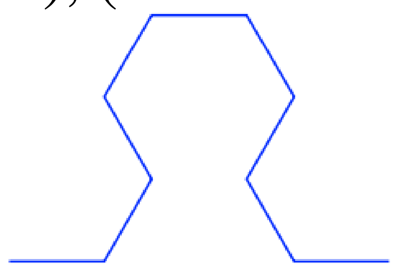
$$\mathbf{G} = \{V, S, \omega, P\}$$

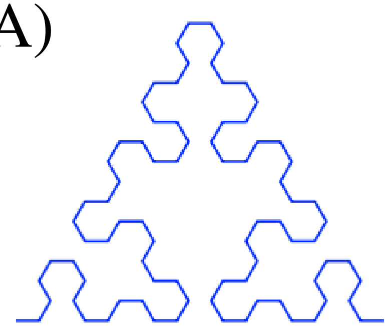
  - V = alphabet, set of symbols that can be replaced (variables)
  - S = set of symbols that remain fixed (constants)
  - ω = string of symbols defining initial state
  - P = production rules

Sierpinski Triangle

- Variables: A, B
  - Draw forward
- Constants: + , -
  - Turn left, right by 60 degrees
- Start: A
- Rules: $(A \rightarrow B\text{-}A\text{-}B)$, $(B \rightarrow A+B+A)$

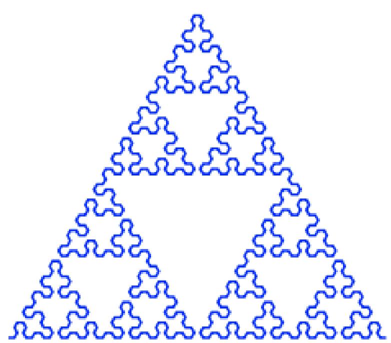
2 iterations

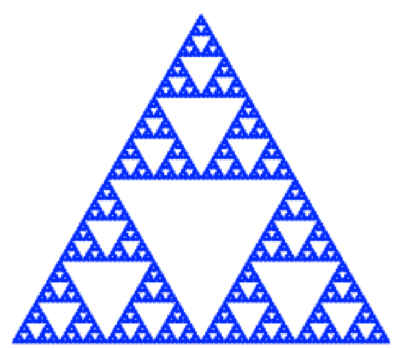




4 iterations

6 iterations





9 iterations

Fractal Fern

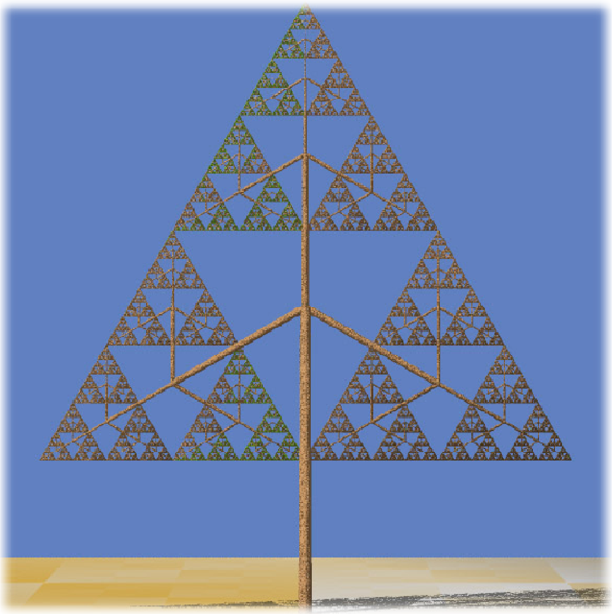
- Variables: X, F
  - X: no drawing operation
  - F: move forward
- Constants: +, –
  - Turn left, right
- Start: X
- Rules:
  $(X \rightarrow F\text{-}[[X]+X]+F[+FX]\text{-}X),(F \rightarrow FF)$
- Stochastic L-system
  - If there is more than one production rule for a symbol, randomly choose one

[Wikipedia]

Fractal Trees

- Recursive generation of trees in 3D
  http://web.comhem.se/solgrop/3dtree.htm
- Model trunk, branches as cylinders
- Change color from brown to green at certain level of recursion

Fractal tree



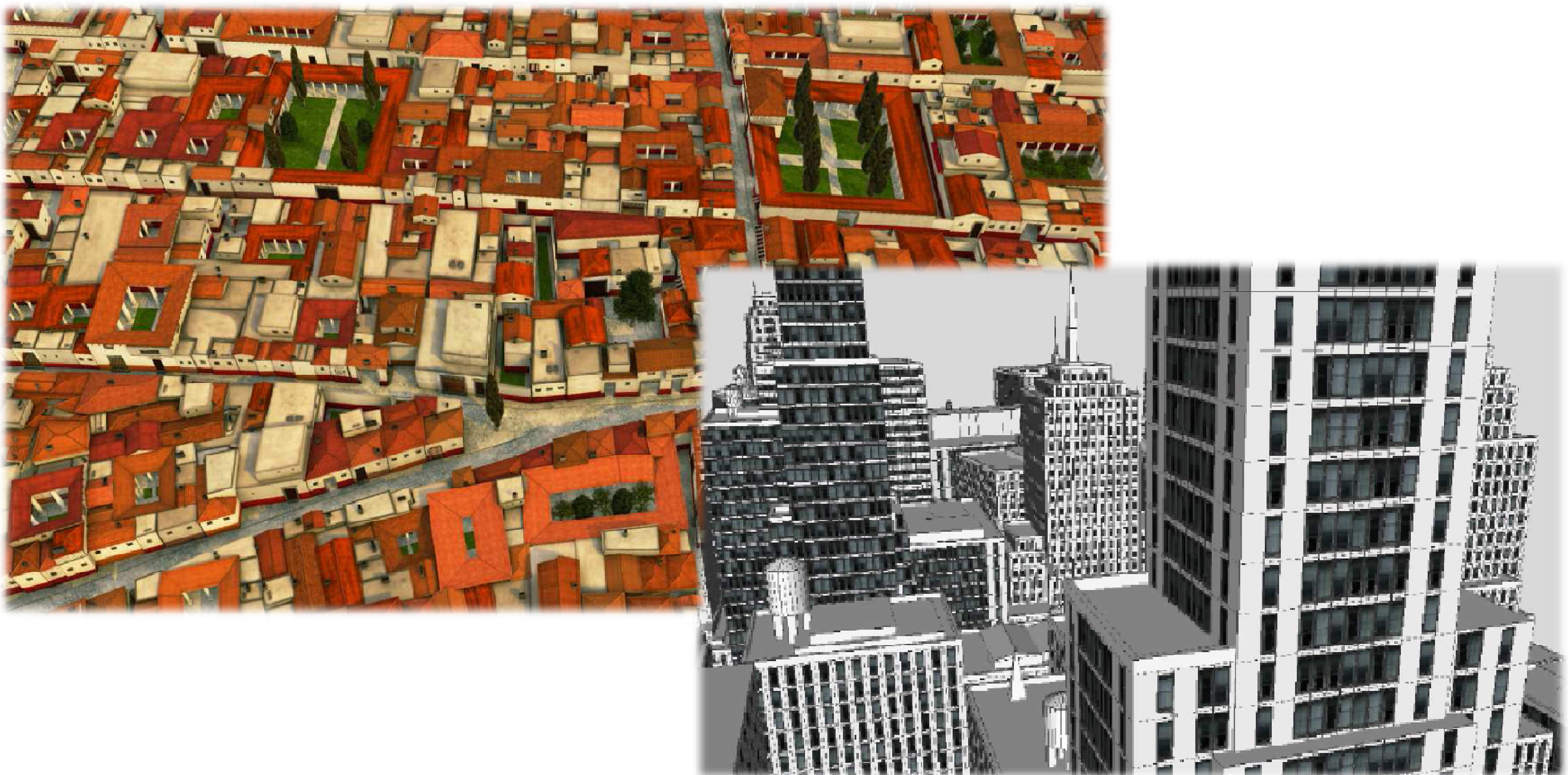
Sierpinski tree

Algorithmic Beauty of Plants

- Online book on algorithmic beauty of plants by Prusinkiewicz
  http://algorithmicbotany.org/papers/#abop

[Prusinkiewicz, http://algorithmicbotany.org/papers/positional.sig2001.pdf]

Buildings, Cities



Pascal Mueller
[http://www.vision.ee.ethz.ch/~pmueller/publications.html]

Demonstration: Procedural Buildings

- fr-041: debris. by Farbrausch, 2007
- 179 KB ZIP file
- http://www.farbrausch.de/

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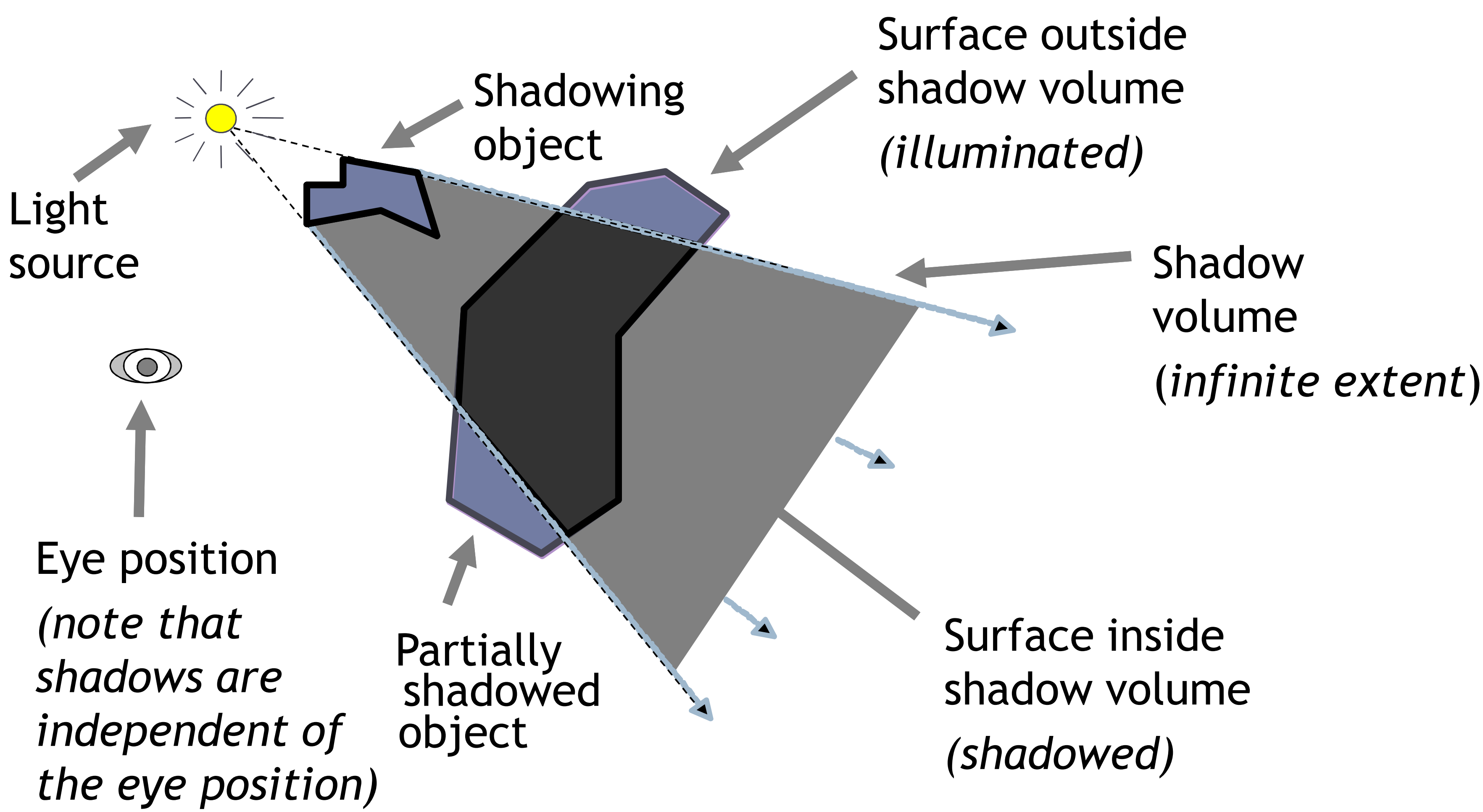
Shadow Volumes

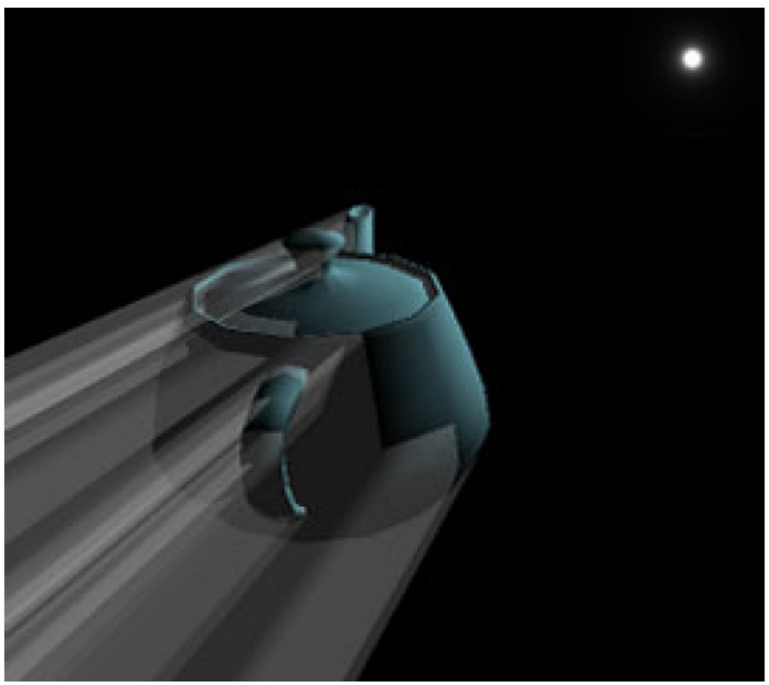


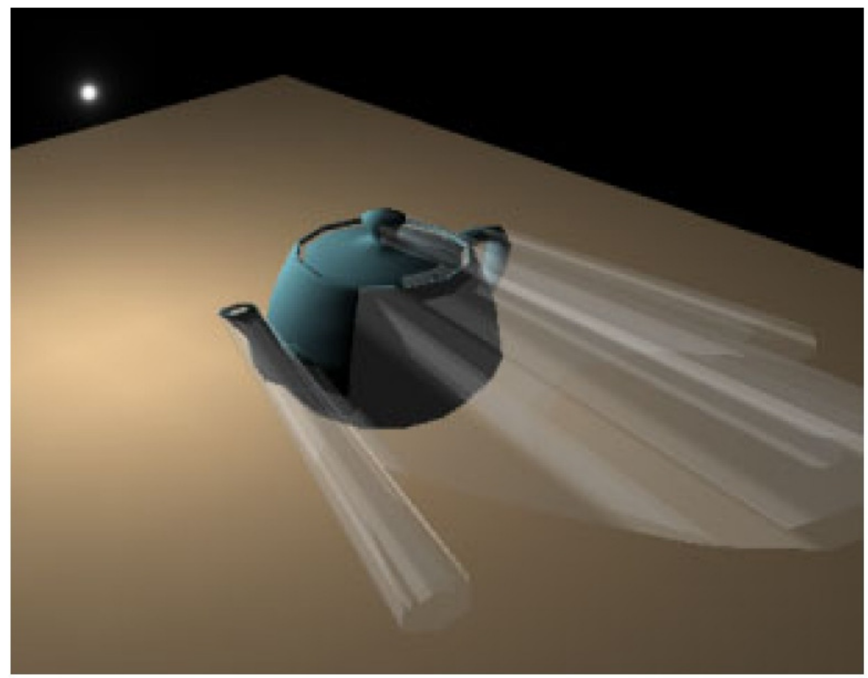
Shading With Shadow Volumes

- Many variations
- Stencil shadow volumes
  - Classic algorithm
  - Hard shadows
- Here, two-pass algorithm for approximate soft shadows
  - Very simple and inaccurate, but often plausible enough
- Many more complicated and more accurate variations exist

Shadow Volume Construction

- Need to generate shadow polygons to bound shadow volume
- Extrude silhouette edges from light source

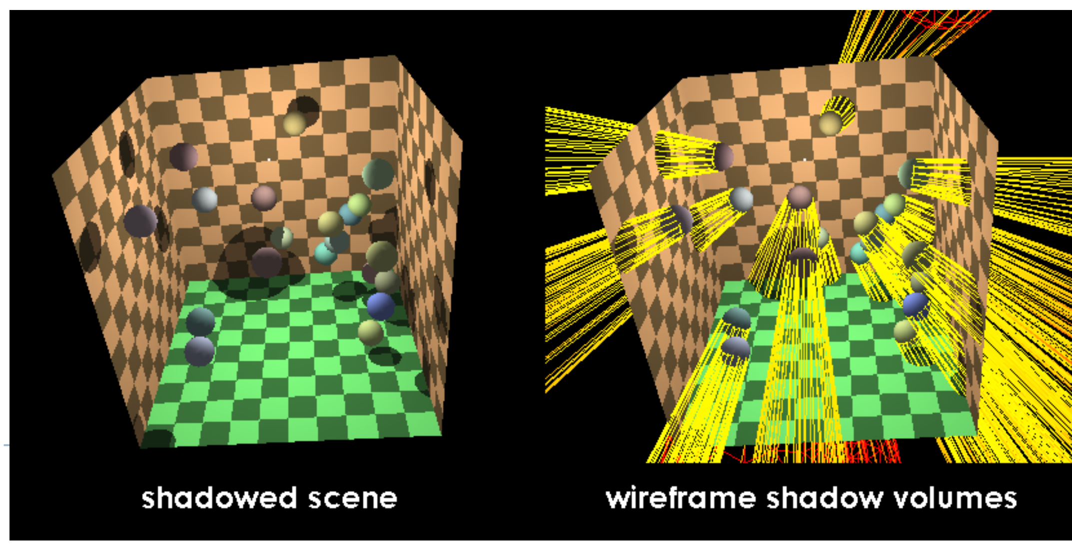




Extruded shadow volumes

Shadow Volume Construction

- Needs to be done on the CPU
- Silhouette edge detection
  - An edge is a silhouette if one adjacent triangle is front facing, the other back facing with respect to the light
- Extrude polygons from silhouette edges



To be continued after midterm…

- Because we have not fully covered shadow volumes, they are not going to be part of the material for the midterm.

Next Lecture

- Second Midterm Exam