CS230 : Computer Graphics

Lecture 4

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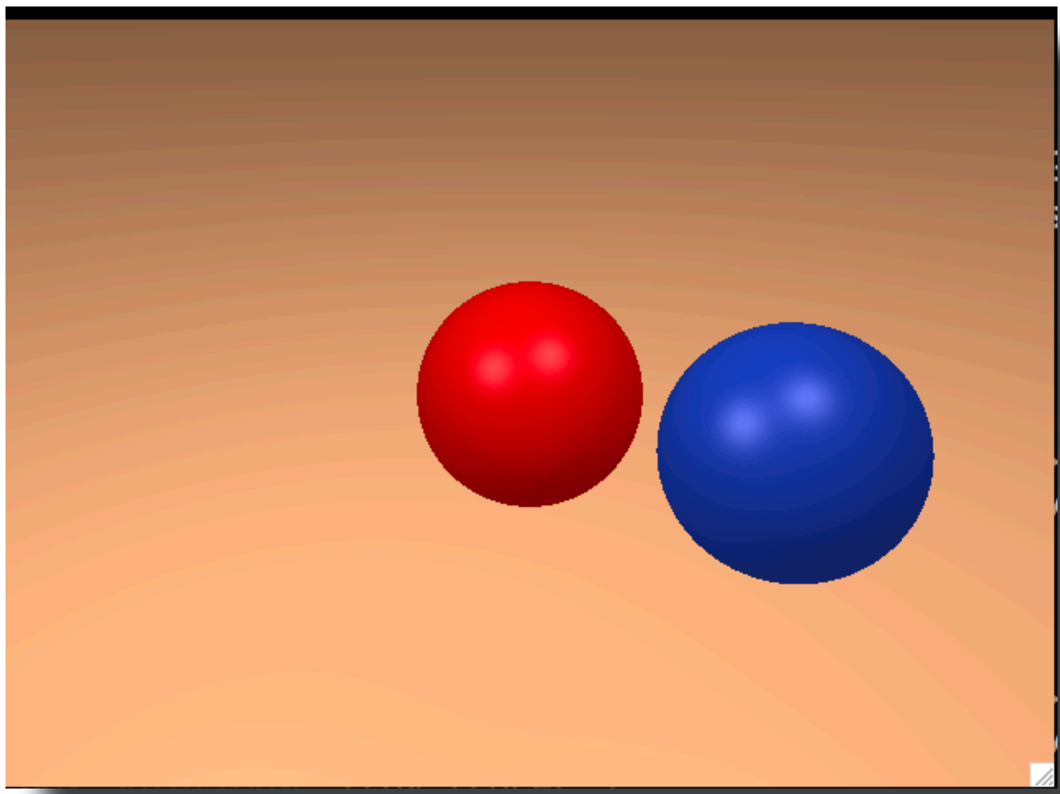
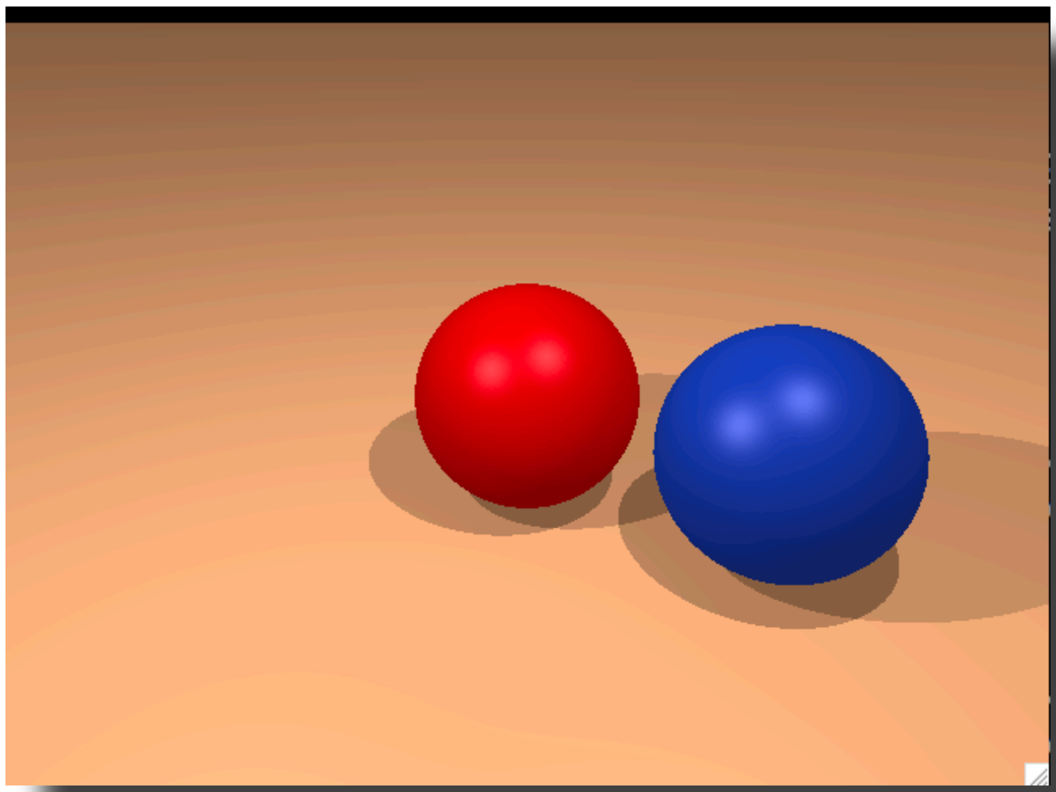
Shadows





Shadows

```
for each pixel do
    compute viewing ray
    if ( ray hits an object with t in [0, inf] ) then
        compute n
        evaluate shading model and set pixel to that color
    else
        set pixel color to the background color
```

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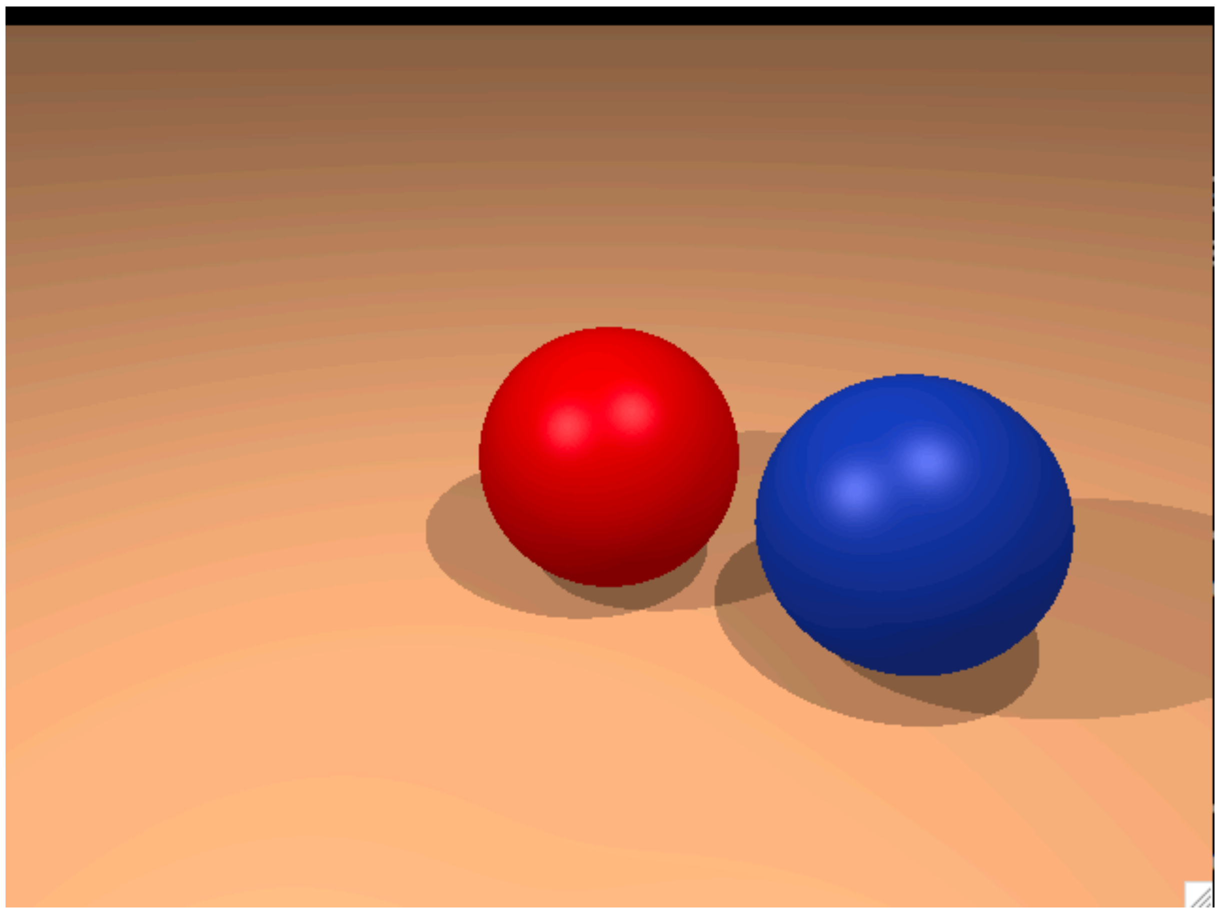
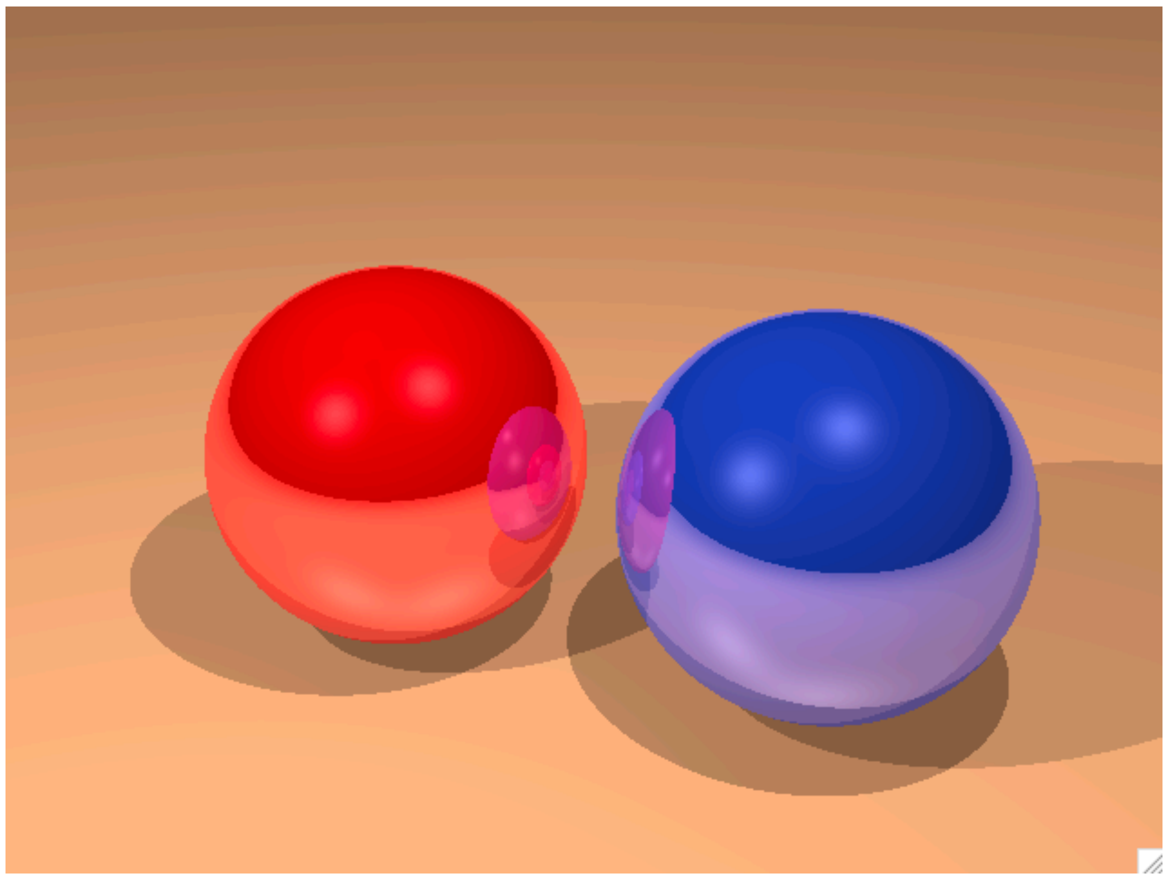
Shadows

```
for each pixel do
    compute viewing ray
    if ( ray hits an object with t in [0, inf] ) then
        compute n
        // e.g., phong shading
        for each light
          add light's ambient component
          compute shadow ray
          if ( ! shadow ray hits an object )
            add light's diffuse and specular components
    else
        set pixel color to the background color
```

Reflections





– Reflective_Shader subclass of Phong shader

Reflections

```
for each pixel do
    compute viewing ray
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Reflections

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for each pixel do
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        compute n
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        set pixel color to the background color
```
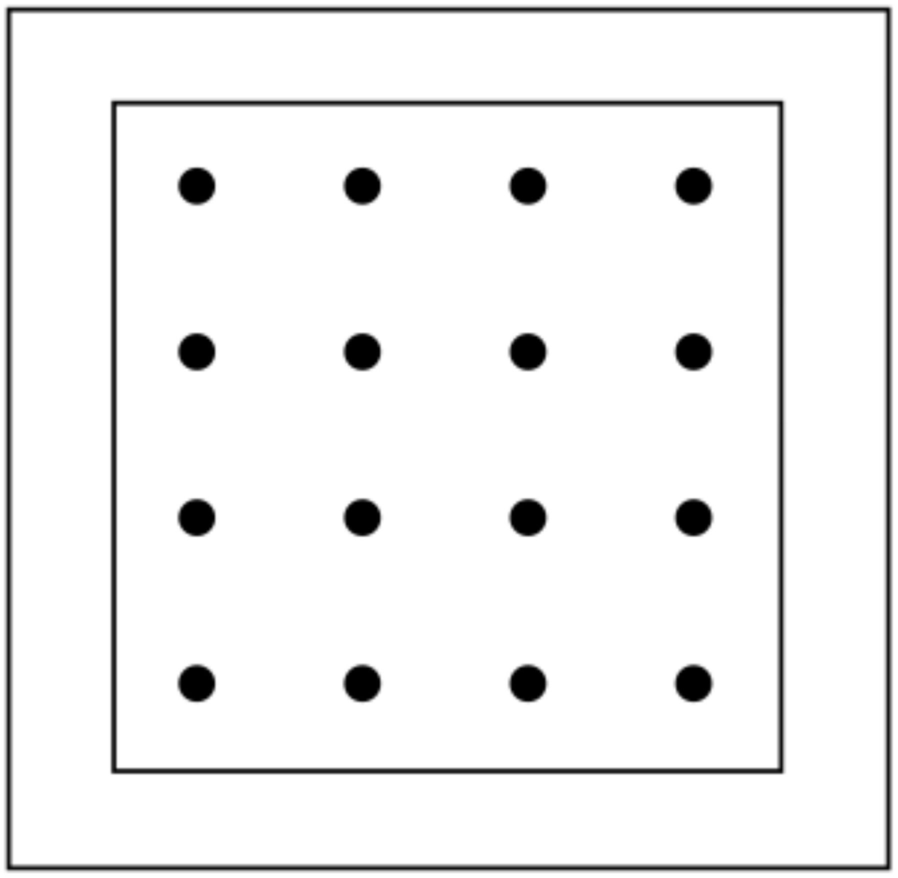
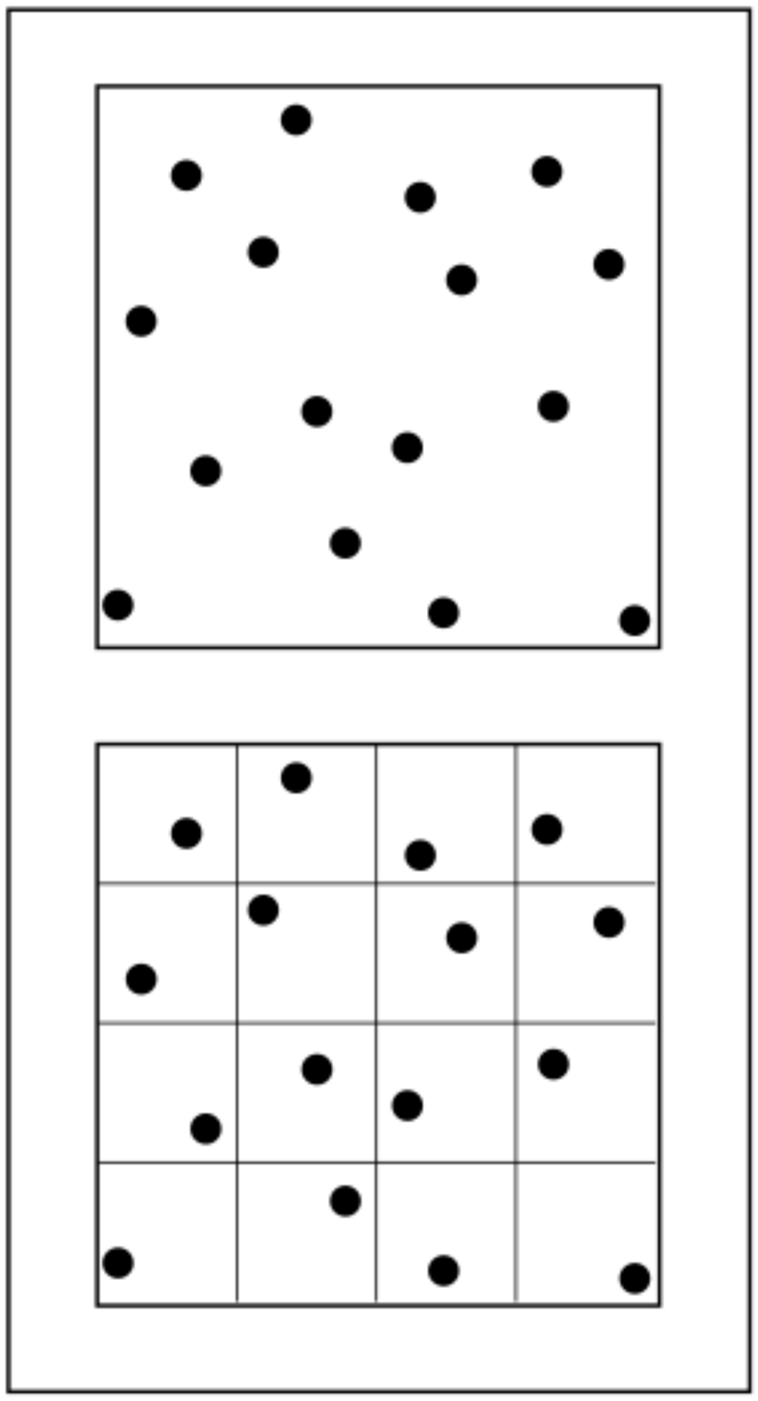

Reflections

```
for each pixel do
    compute viewing ray
    pixel color = cast_ray(viewing ray)

cast_ray:
    if ( ray hits an object with t in [0, inf] ) then
        compute n
        return color = shade_surface
    else
        return color = to the background color

shade_surface:
    color = ...
    compute reflected ray
    return color = color + k * cast_ray(reflected ray)
```

Distribution Ray Tracing

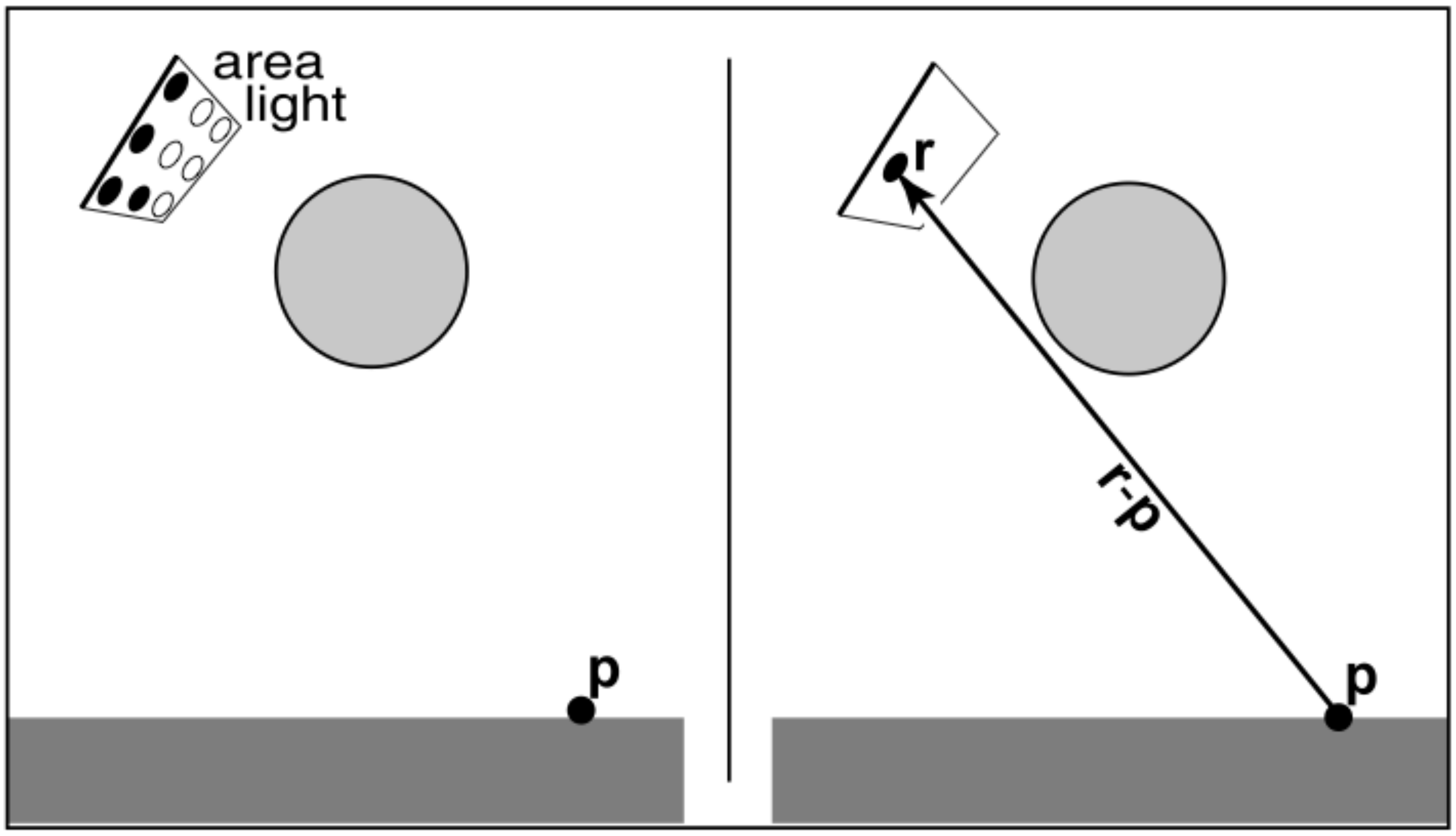
Anti-aliasing

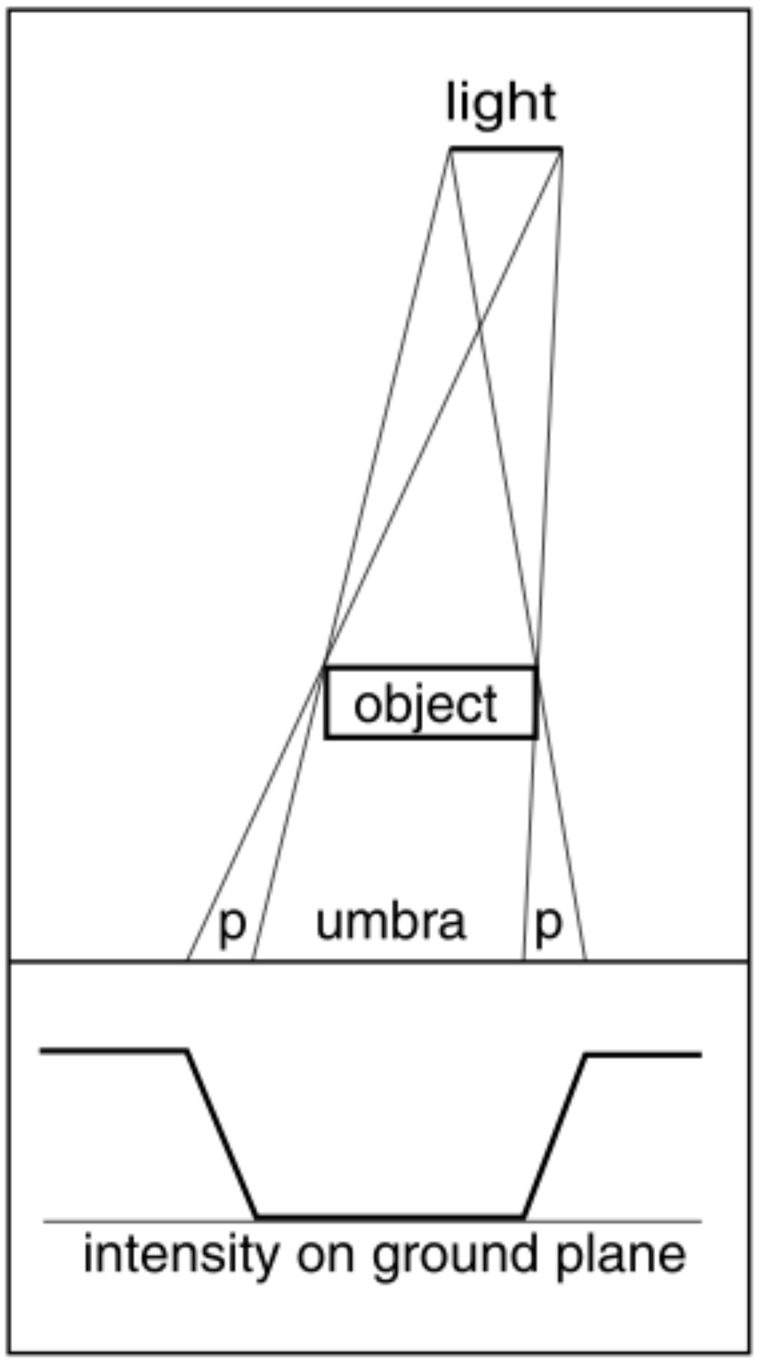




[Shirley and Marschner]

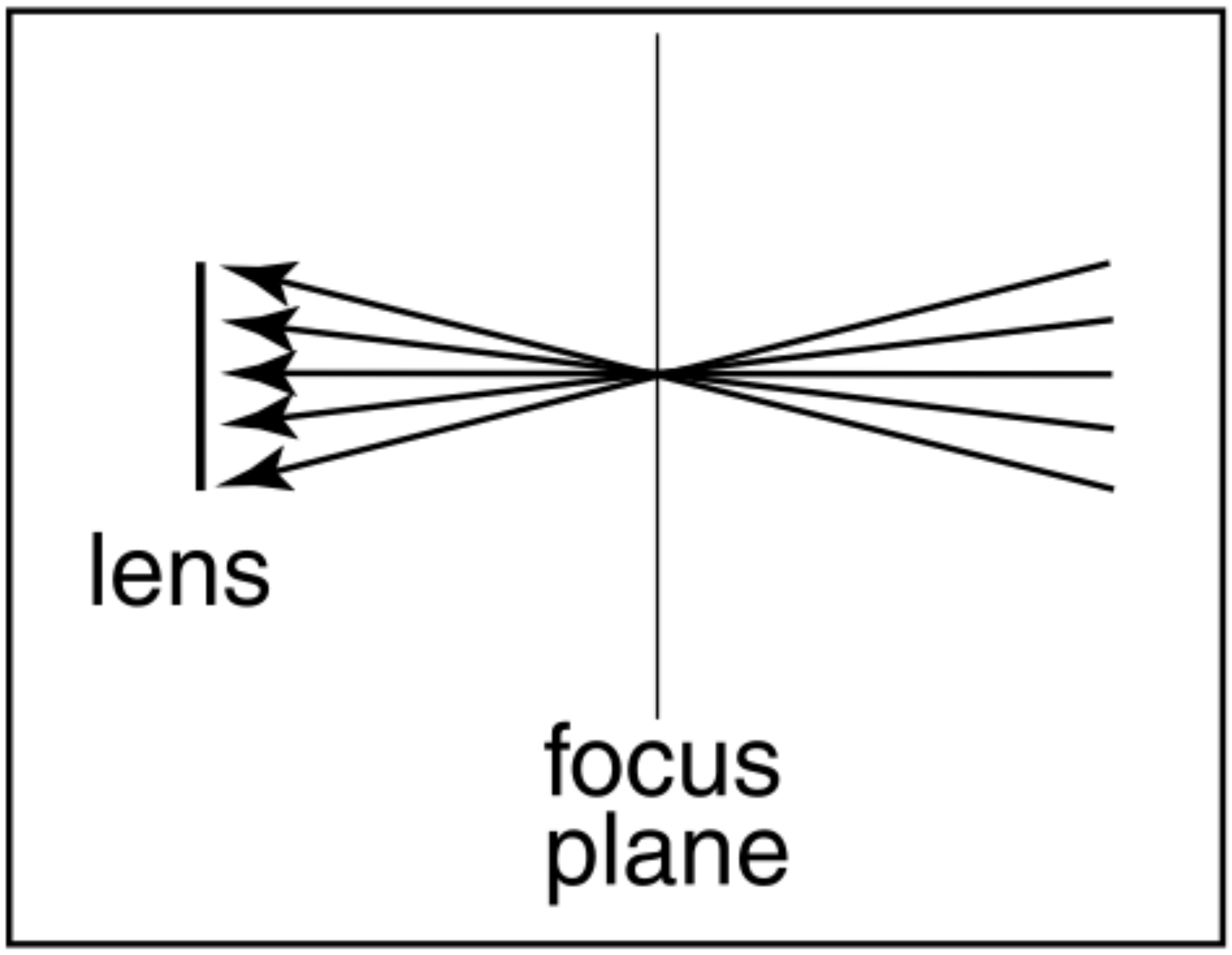
Soft Shadows

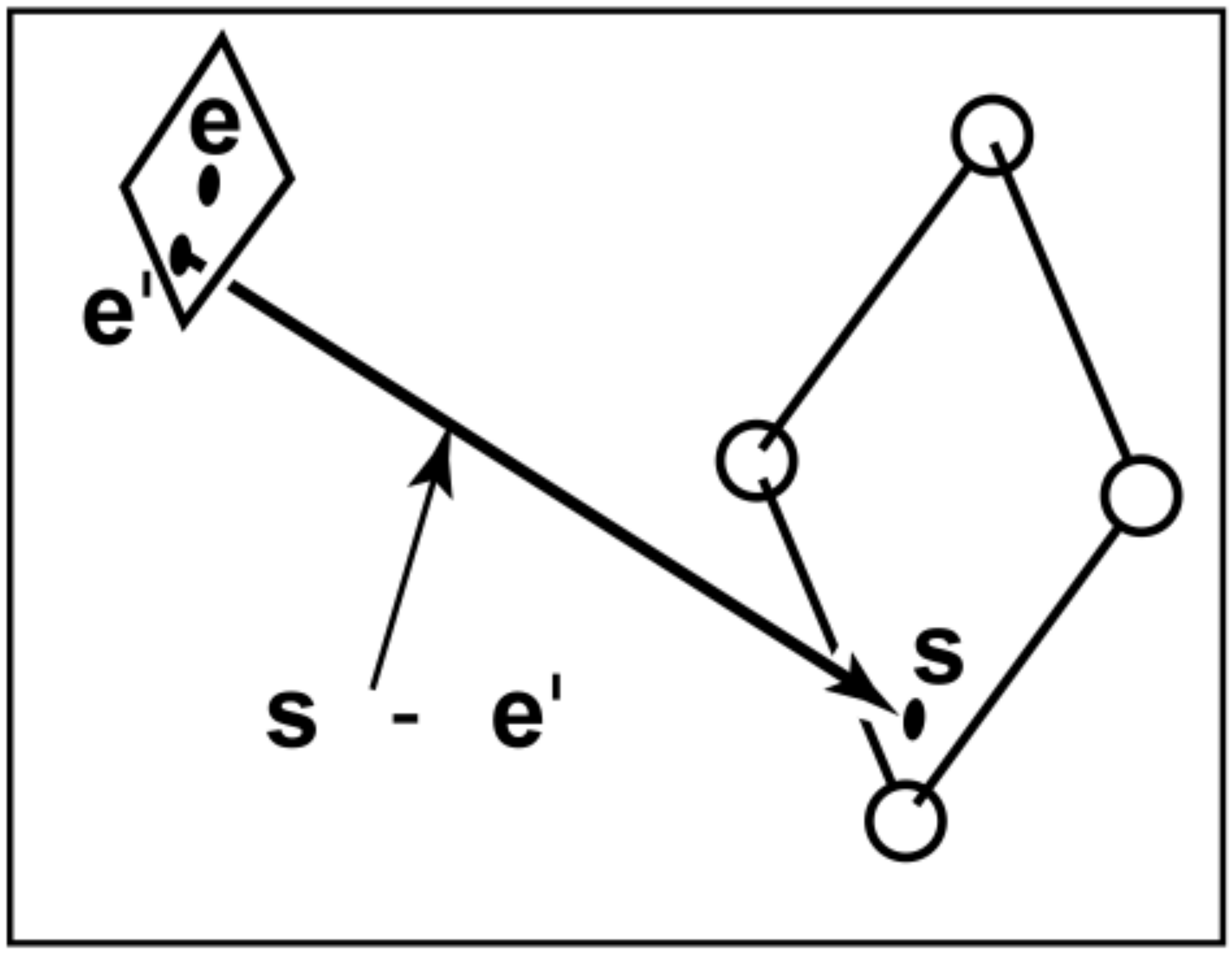


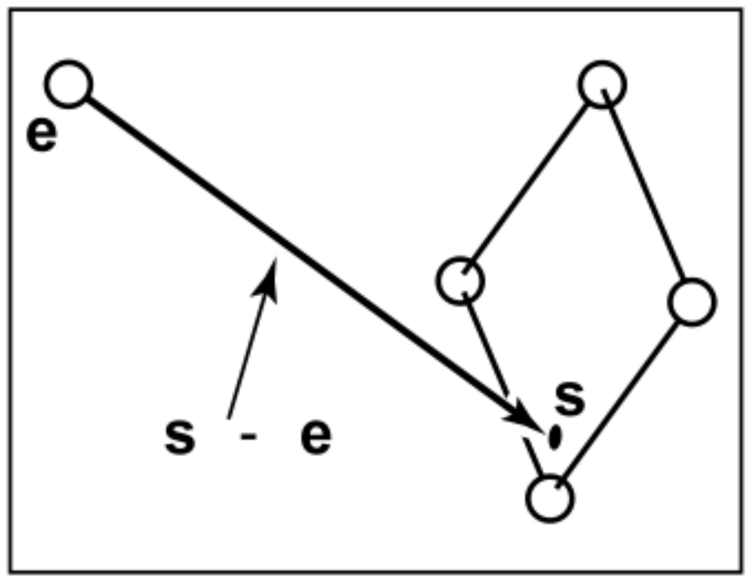


[Shirley and Marschner]

Soft Focus







[Shirley and Marschner]

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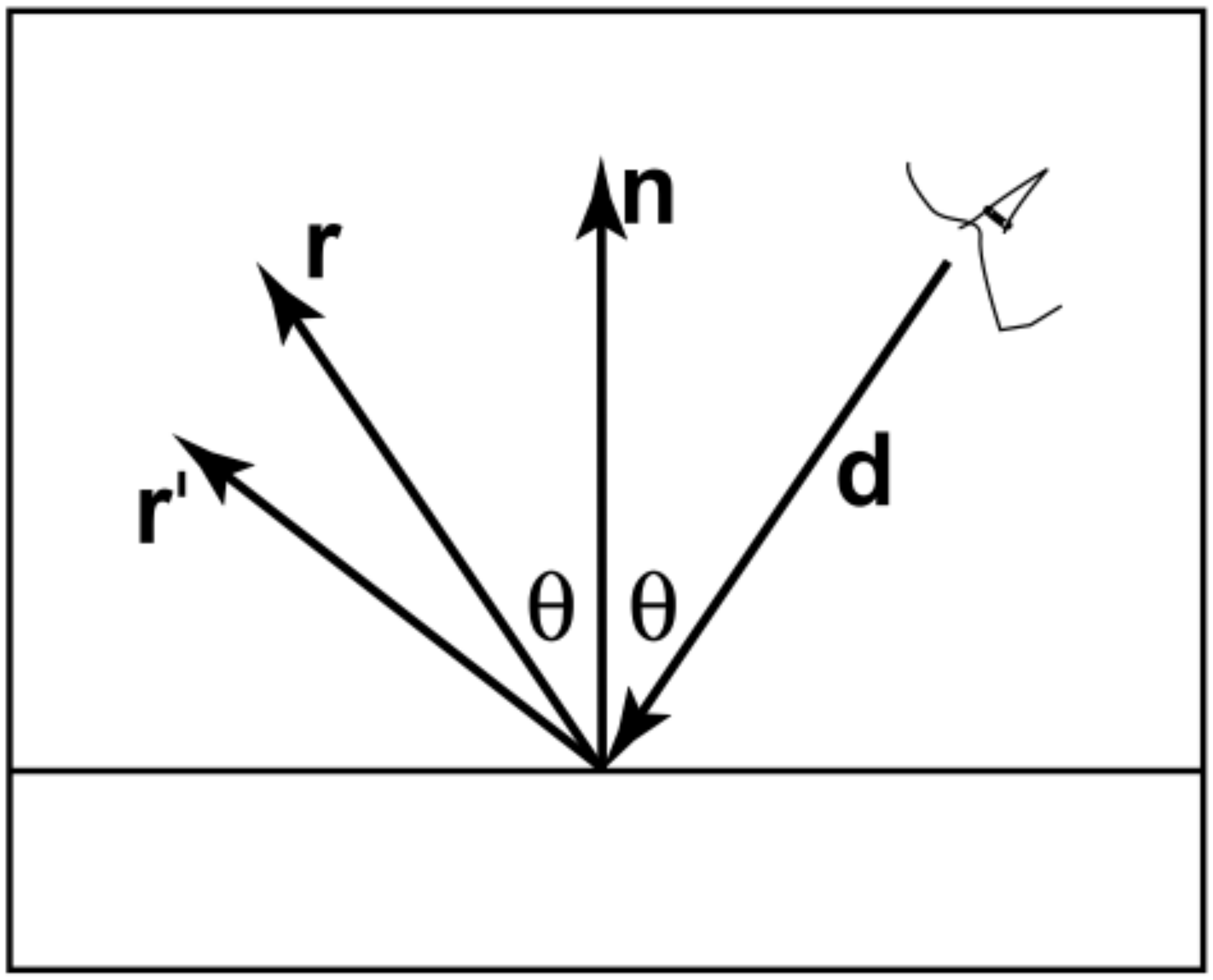
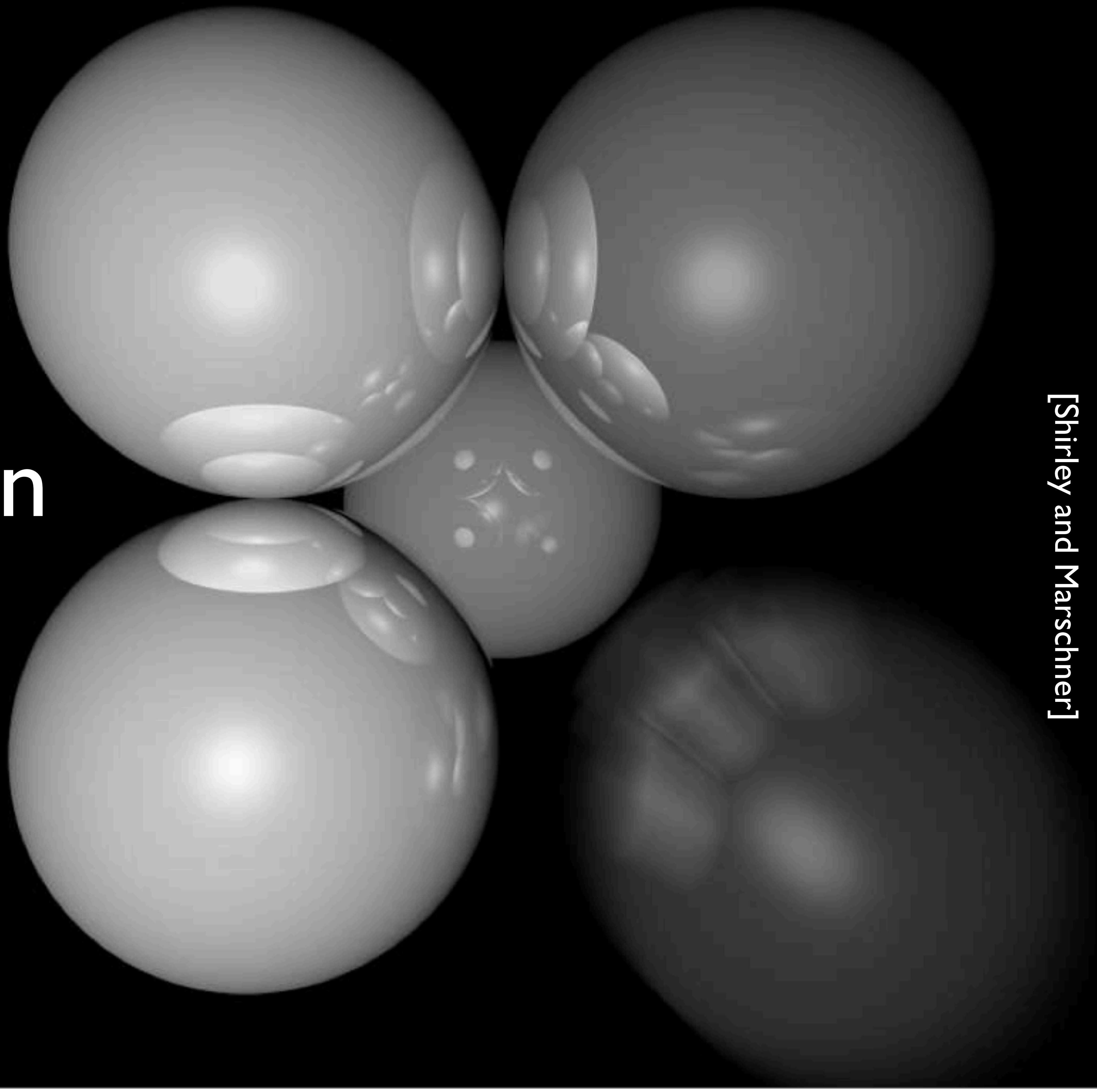
Fuzzy Reflections



[Shirley and Marschner]

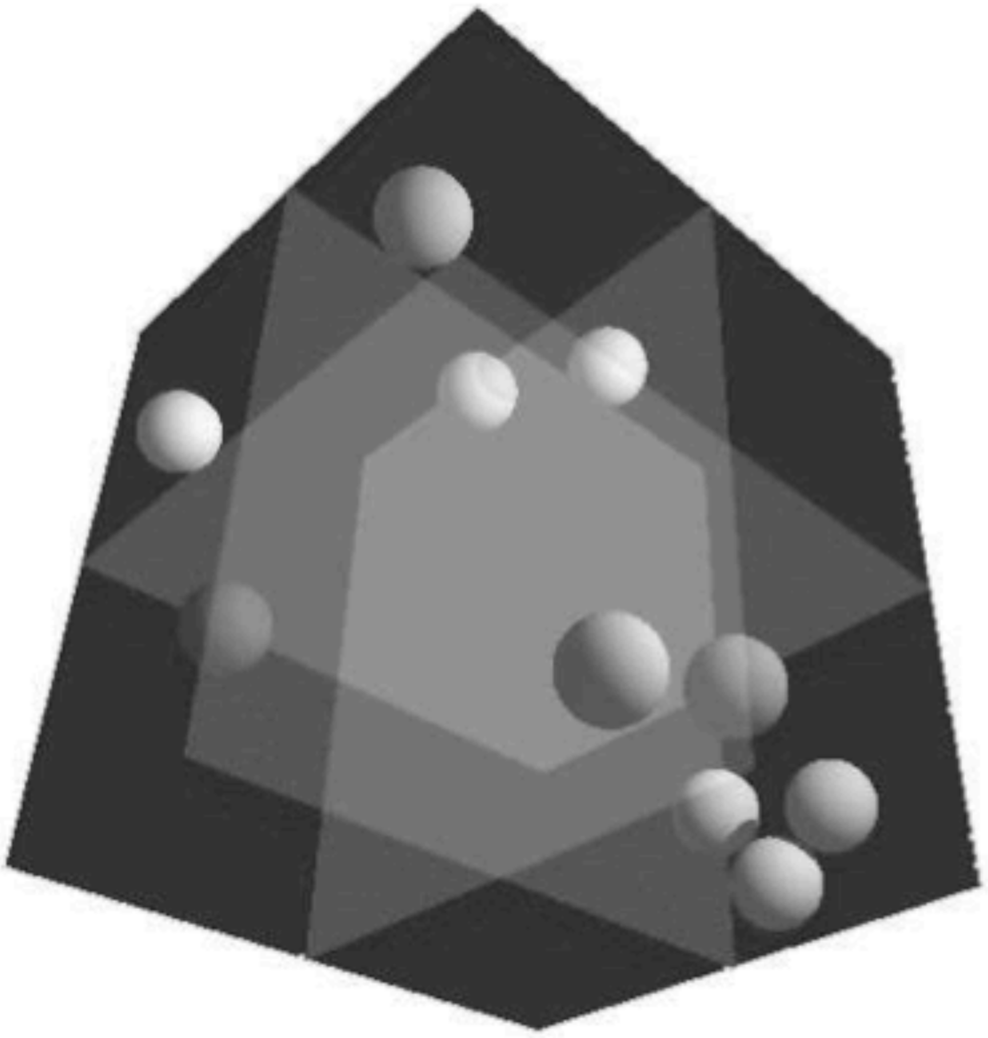
Motion Blur

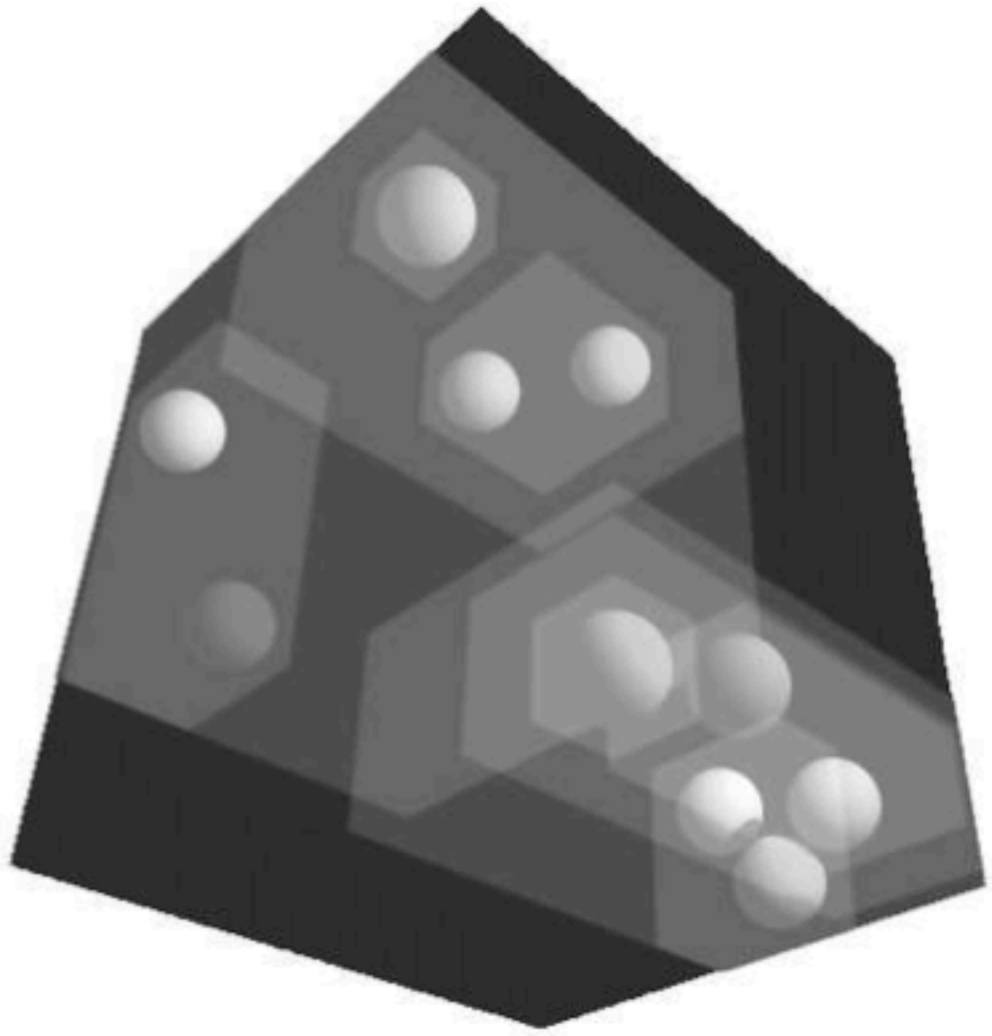


[Shirley and Marschner]

Acceleration Structures

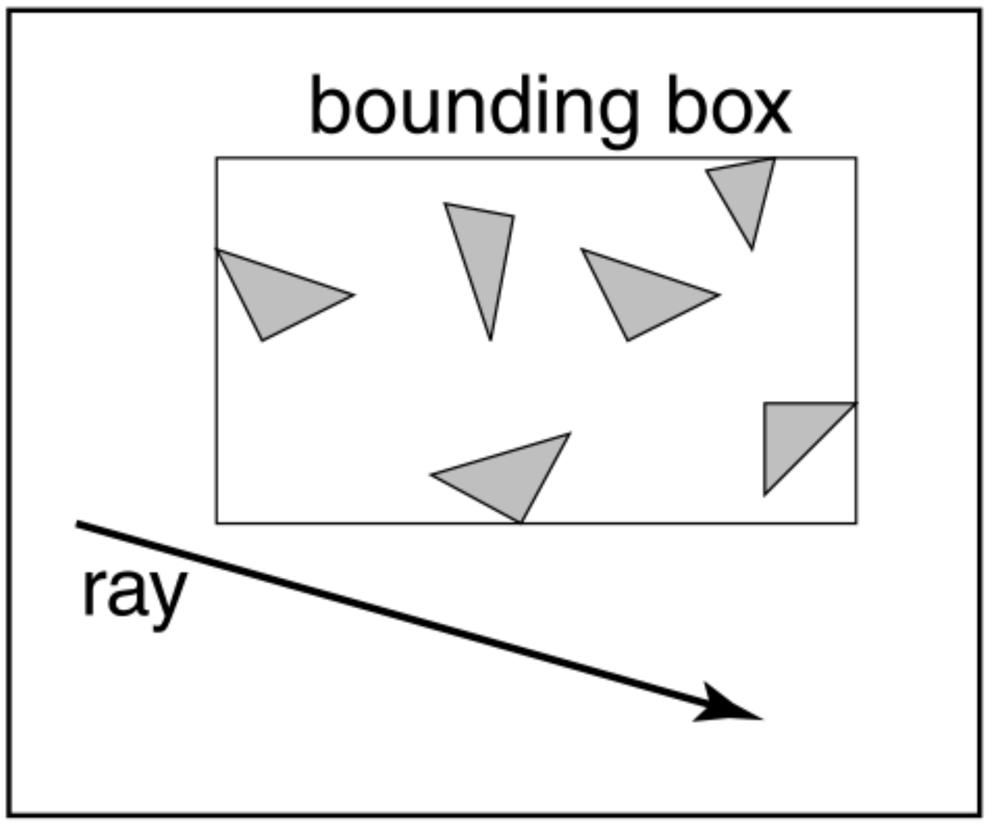
Acceleration Structures

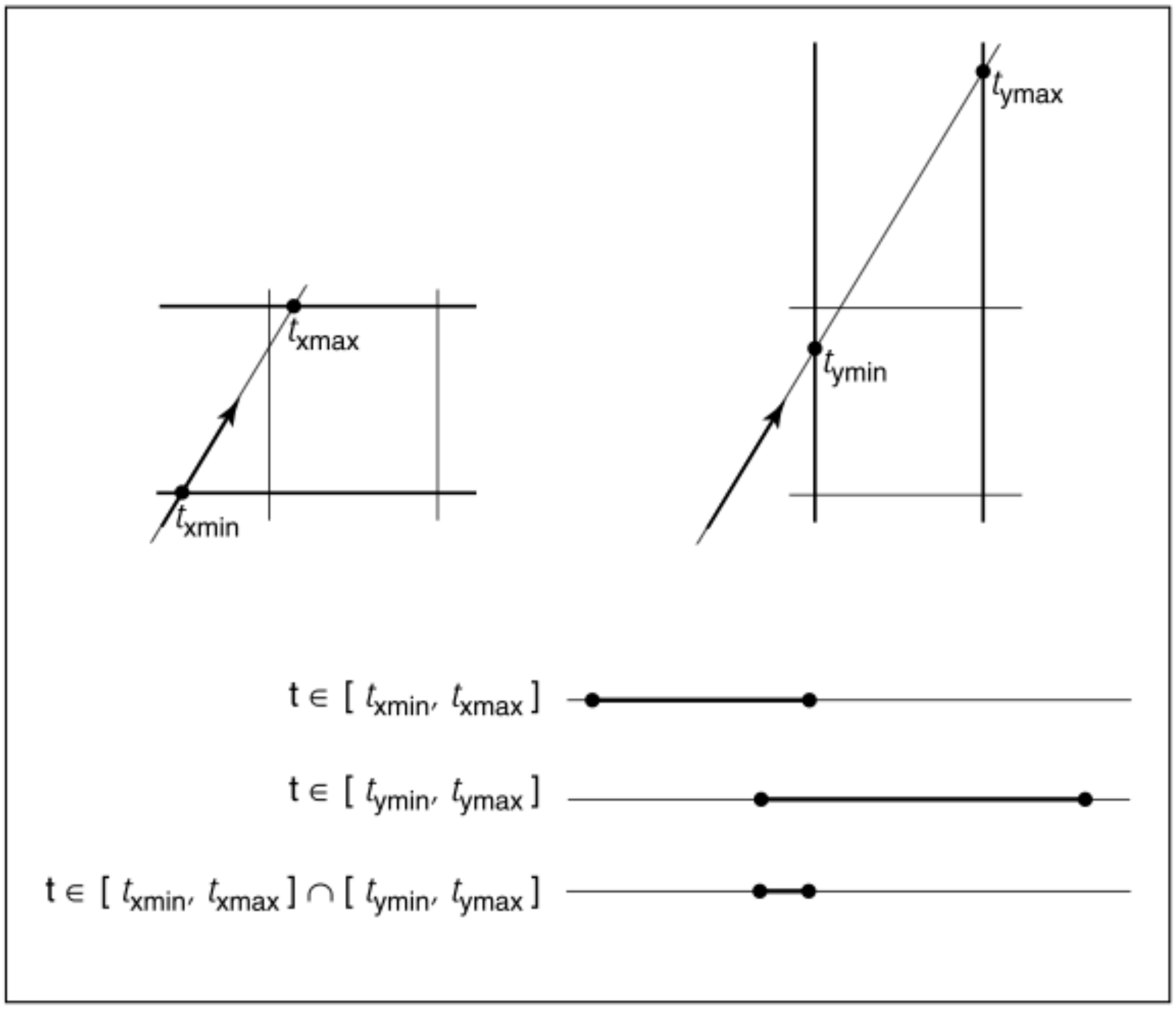




[Shirley and Marschner]

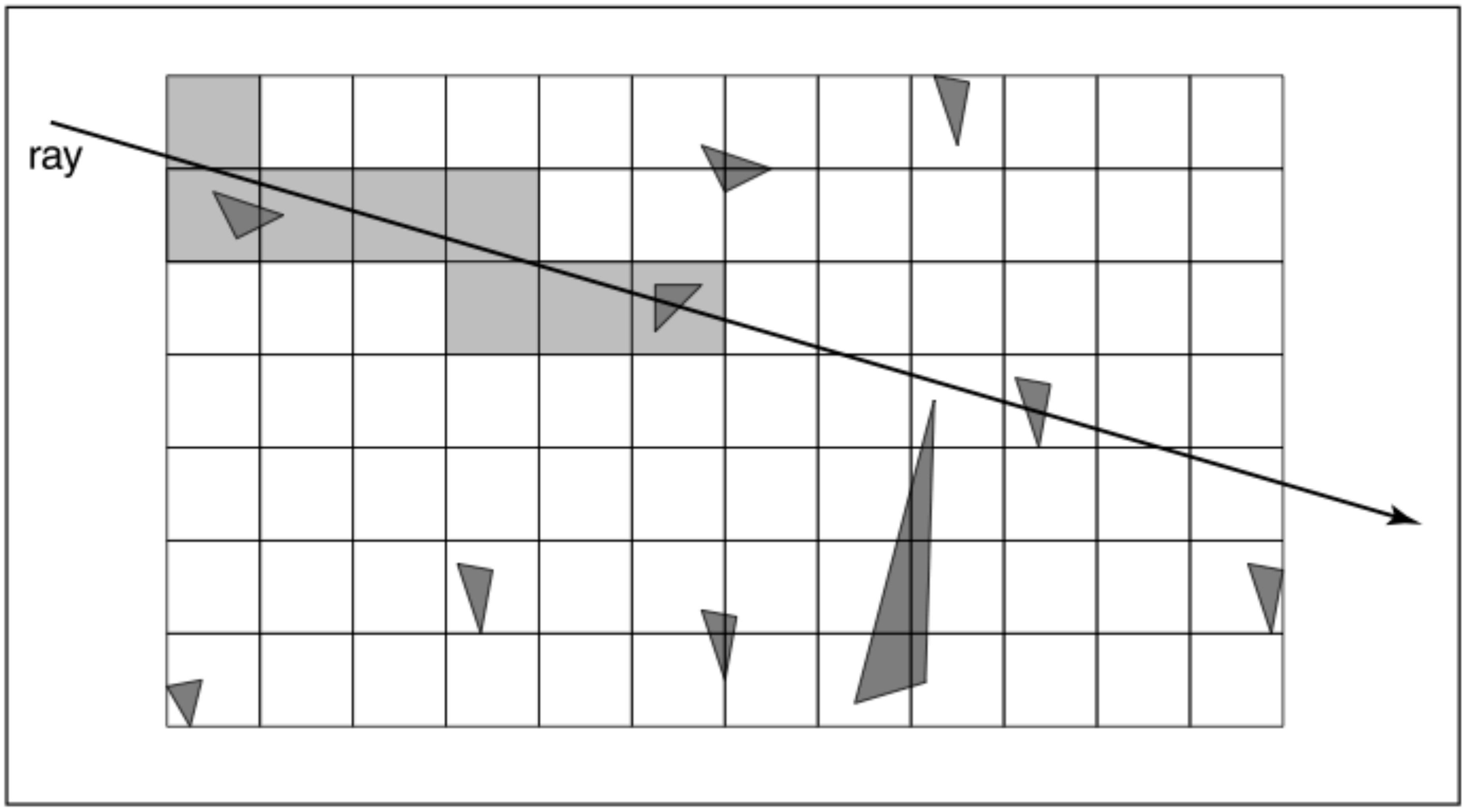
Bounding boxes





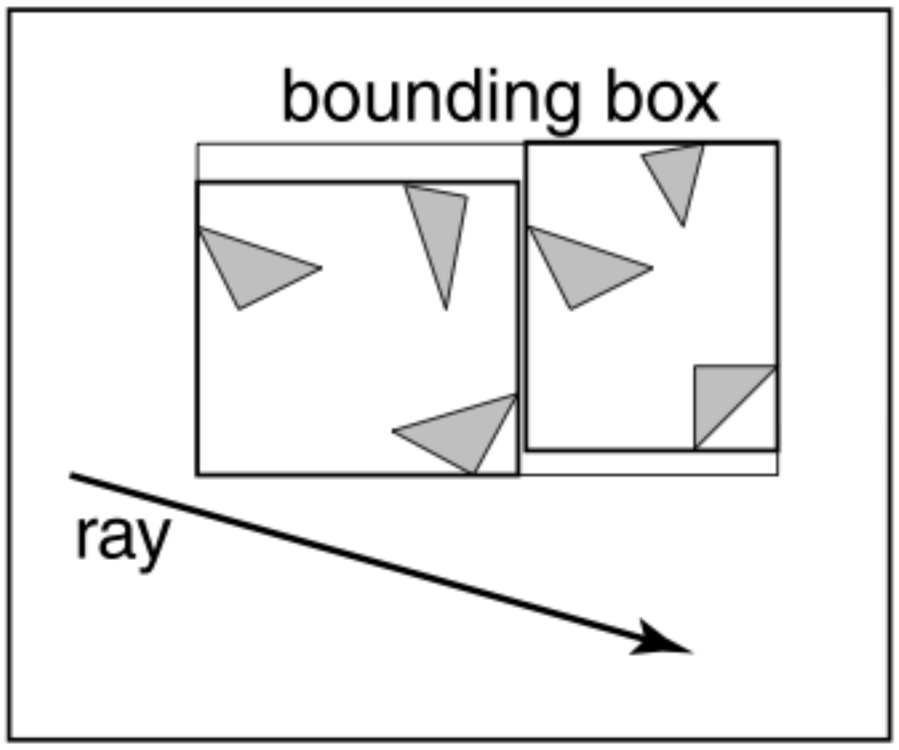
[Shirley and Marschner]

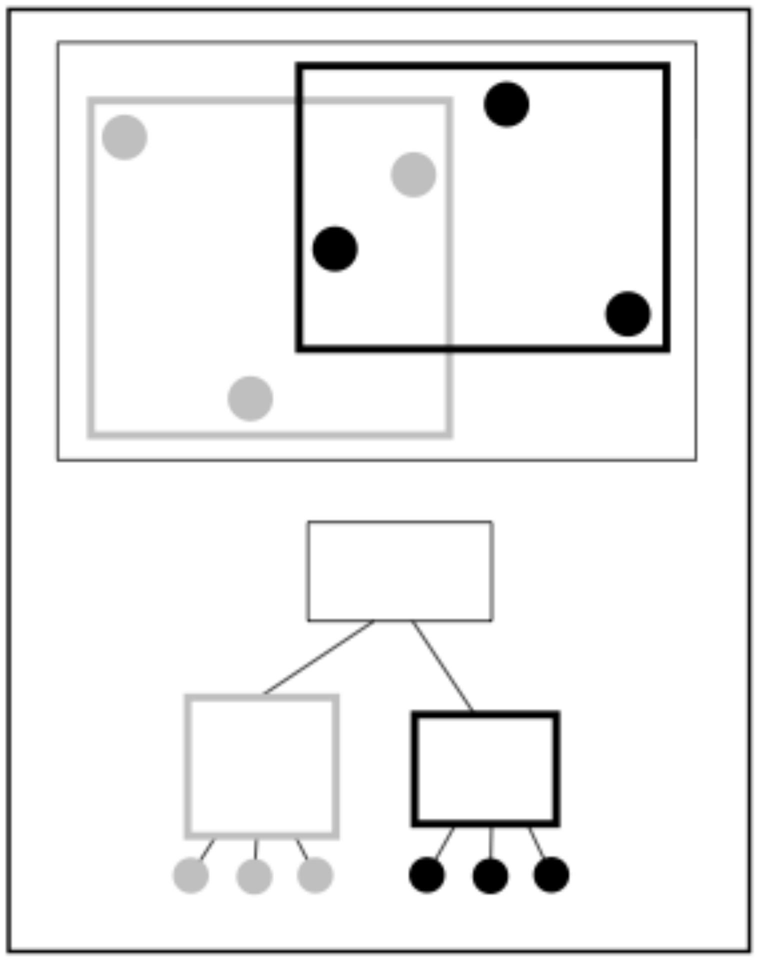
Uniform Spatial Partitioning



[Shirley and Marschner]

Bounding Volume Hierarchy





[Shirley and Marschner]

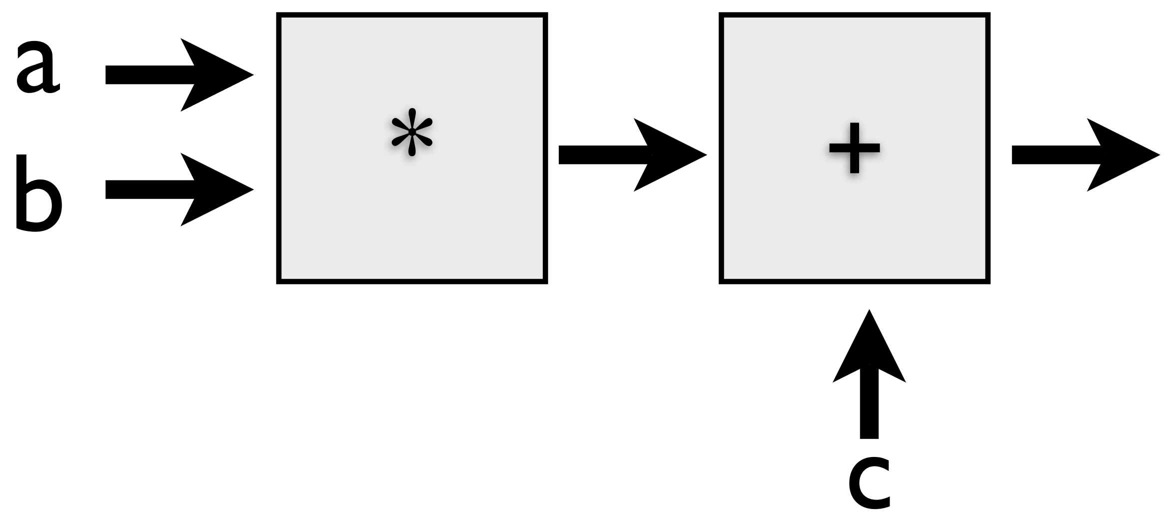
Graphics Pipeline

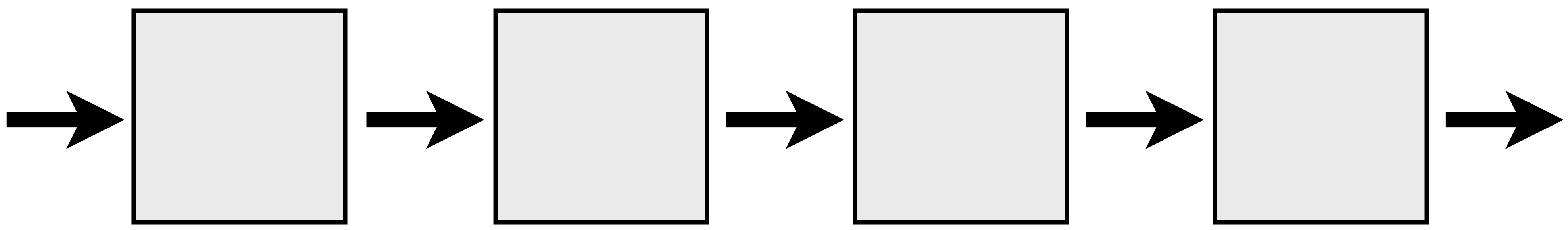
Z-buffer Rendering

- Z-buffering is very common approach, also often accelerated with hardware
- OpenGL is based on this approach

Pipelining operations

An arithmetic pipeline that computes c+(a*b)



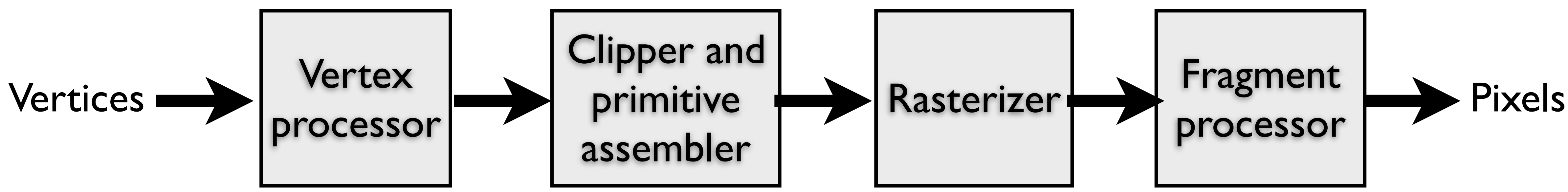


By pipelining the arithmetic operation, the **throughput**, or rate at which data flows through the system, has been **doubled**

If the pipeline had more boxes, the **latency, or time it takes one datum to pass through the system**, would be higher

throughput and latency must be balanced

3D graphics pipeline



Geometry: objects – made of primitives – made of vertices
Vertex processing: coordinate transformations and color
Clipping and primitive assembly: output is a set of primitives
Rasterization: output is a set of fragments for each primitive
Fragment processing: update pixels in the frame buffer

the pipeline is best when we are doing the same operations on many data sets
-- good for computer graphics!! where we process larges sets of vertices and pixels in the same manner

1. **Geometry**: objects – made of primitives – made of vertices
2. **Vertex processing:** coordinate transformations and color
3. **Clipping and primitive assembly:** use clipping volume. must be primitive by primitive rather than vertex by vertex. therefore vertices must be assembled into primitives before clipping can take place. Output is a set of primitives.
4. **Rasterization:** primitives are still in terms of vertices -- must be converted to pixels. E.g., for a triangle specificied by 3 vertices, the rasterizer must figure out which pixels in the frame buffer fill the triangle. Output is a set of **fragments for each primitive**. A fragment is like a **potential pixel.** Fragments can carry depth information used to figure out if they lie behind other fragments for a given pixel.
5. **Fragment processing:** update pixels in the frame buffer. some fragments may not be visible. texture mapping and bump mapping. blending.

3D graphics pipeline

- optimized for drawing 3D triangles with shared vertices
- map 3D vertex locations to 2D screen locations
- shade triangles and draw them in back to front order using a z-buffer
- speed depends on # of triangles
- most operations on vertices can be represented using a 4D coordinate space - 3D position + homogeneous coordinate for perspective viewing
  - 4x4 matrices and 4-vectors

– use varying level of detail – fewer triangles for distant objects
1. construct shapes from primitives – points, lines, polygons, images, bitmaps, (mathematical descriptions of objects) – specify the **model**

Primitives and Attributes

Choice of primitives

- Which primitives should an API contain?
  - small set - supported by hardware, *or*
  - lots of primitives - convenient for user

Choice of primitives

- Which primitives should an API contain?

  ➡**small set - supported by hardware**

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Performance is in **10s millions polygons/sec** -- **portability, hardware support** key

Choice of primitives

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➡**small set - supported by hardware**

  - lots of primitives - convenient for user

GPUs are optimized for
points, **lines**, and **triangles**

Choice of primitives

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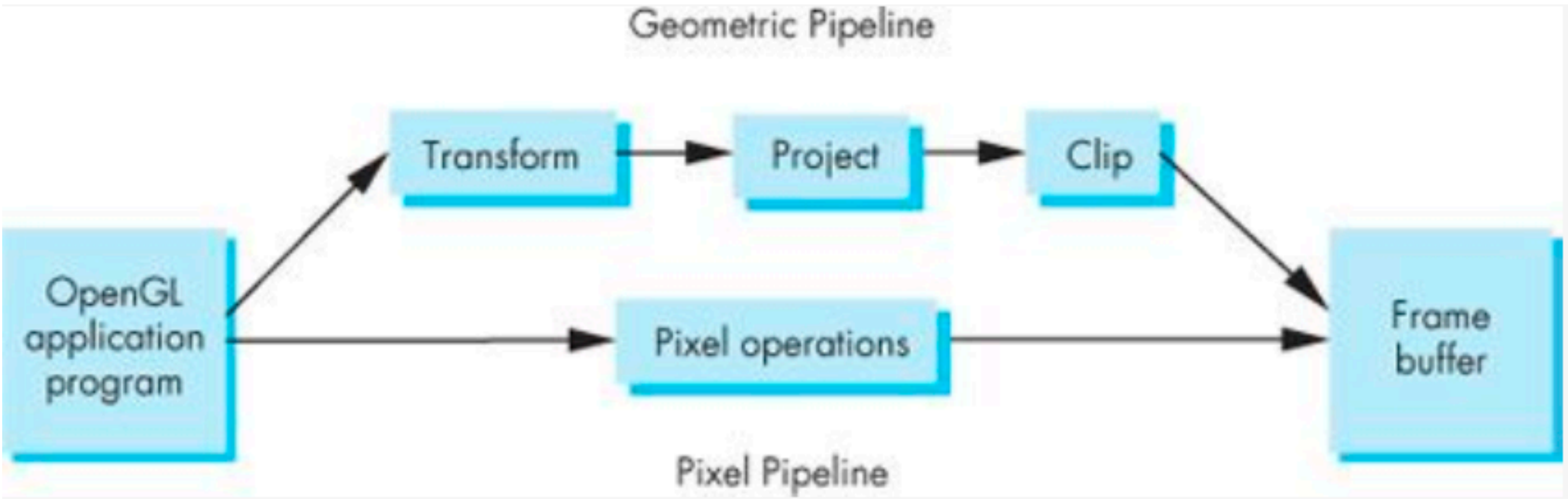
GPUs are optimized for
points, **lines**, and **triangles**

Other geometric shapes will be built out of these

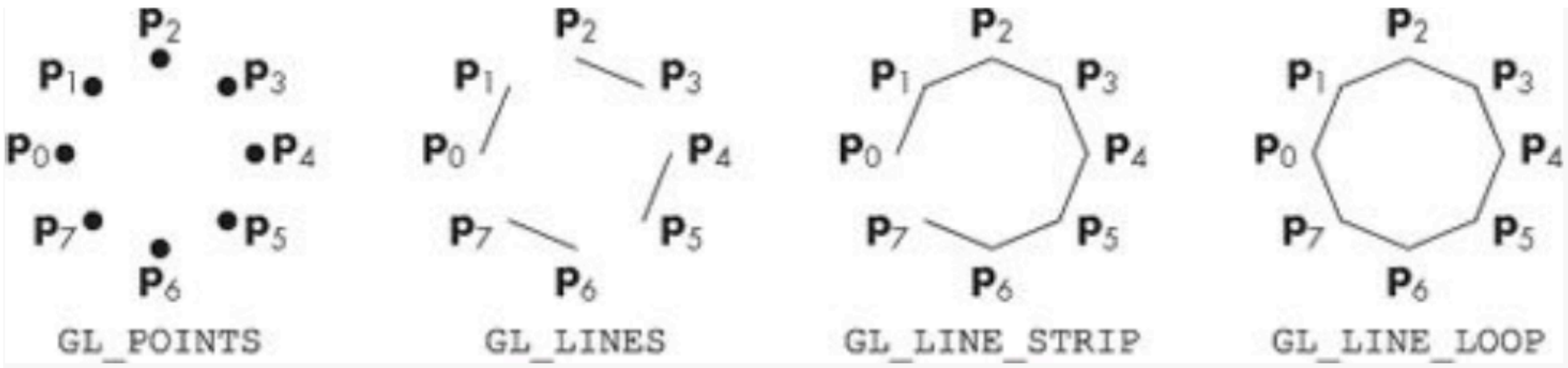
Two classes of primitives



Angel and Shreiner

Geometric : points, lines, polygons
Image : arrays of pixels

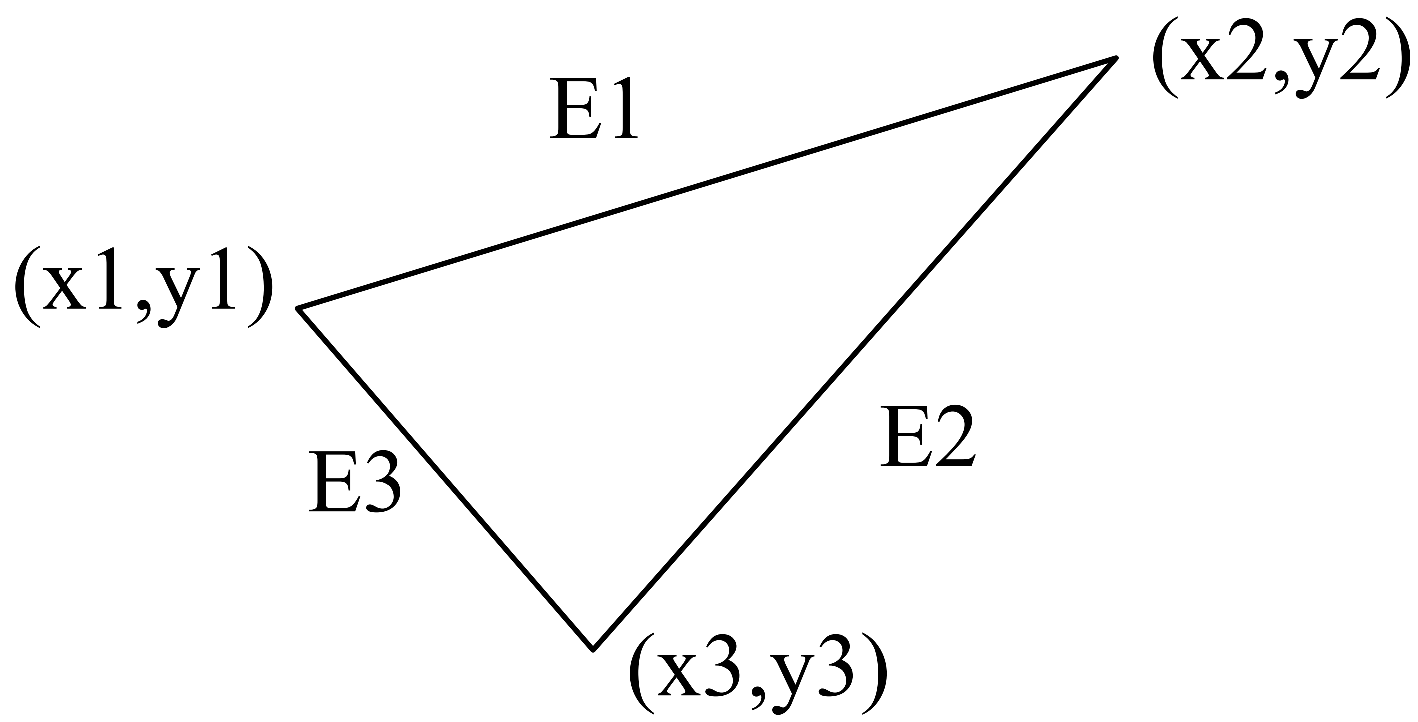
Point and line segment types



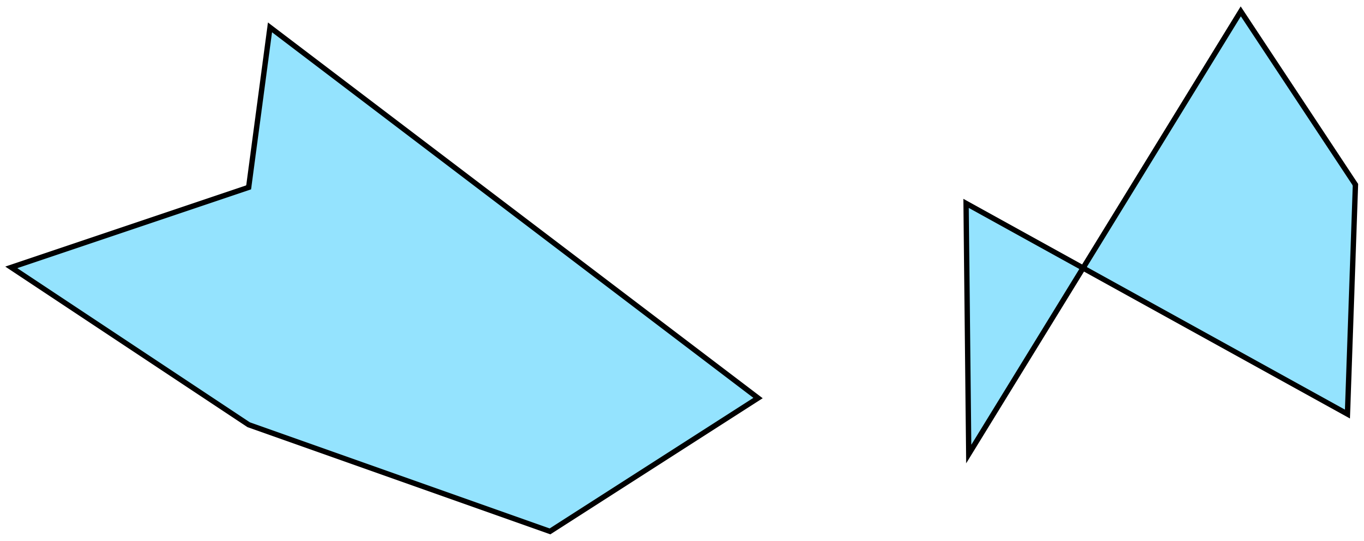
Angel and Shreiner

Polygons

- Multi-sided planar element composed of edges and vertices.
- Vertices (singular vertex) are represented by points
- Edges connect vertices as line segments

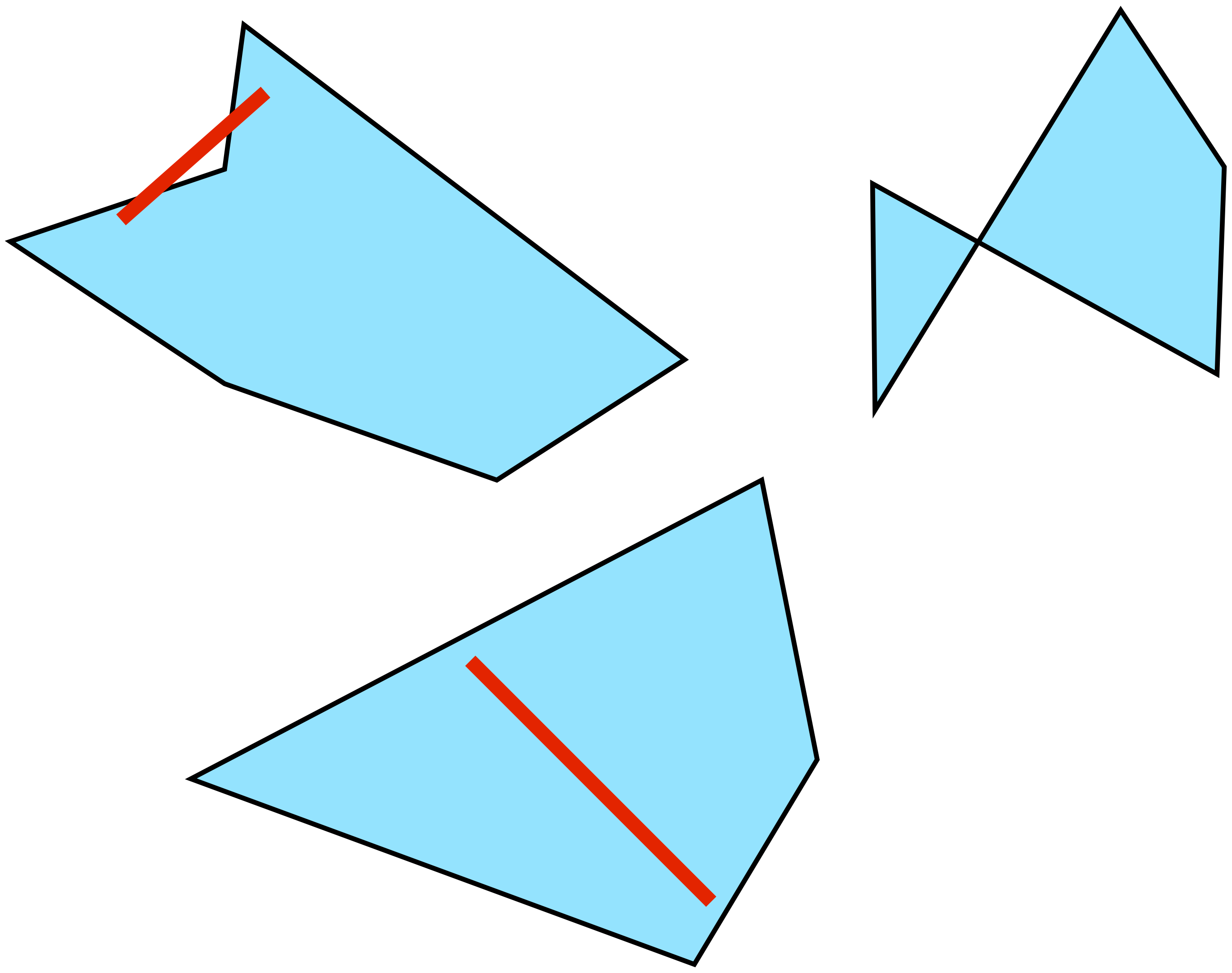


Valid polygons



- Simple
- Convex
- Flat

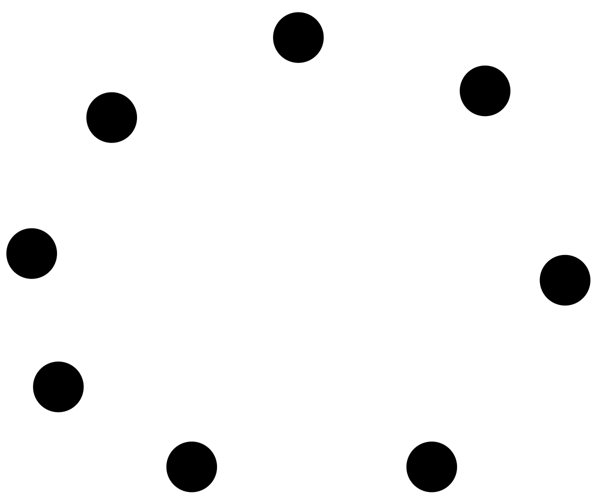
Valid polygons



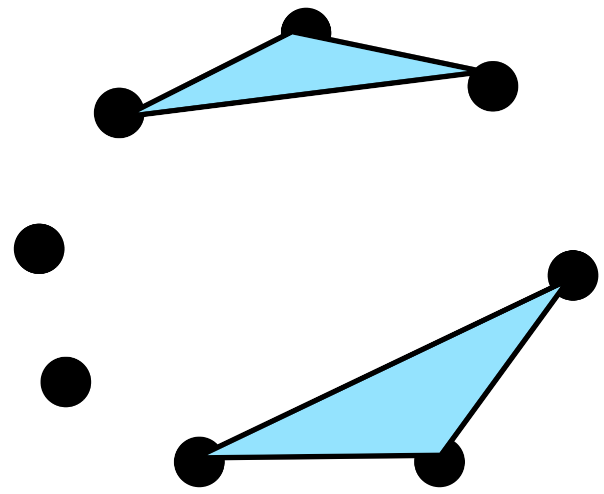
- Simple
- Convex
- Flat

OpenGL polygons

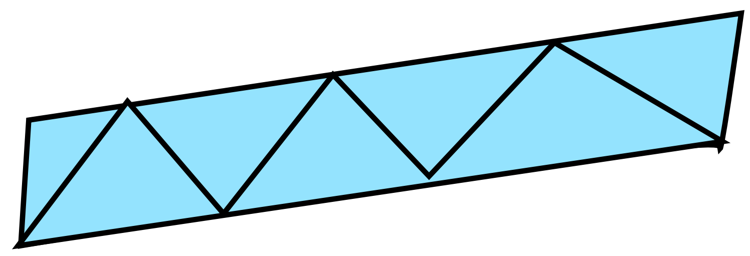
- Only triangles are supported (in latest versions)



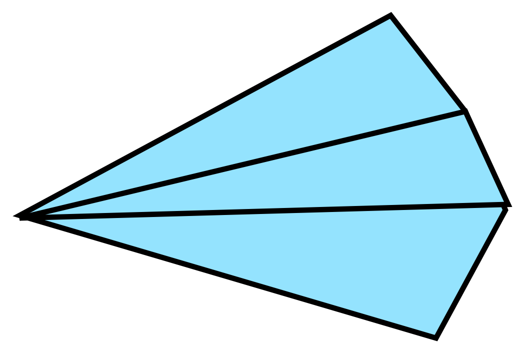
GL_POINTS



GL_TRIANGLES

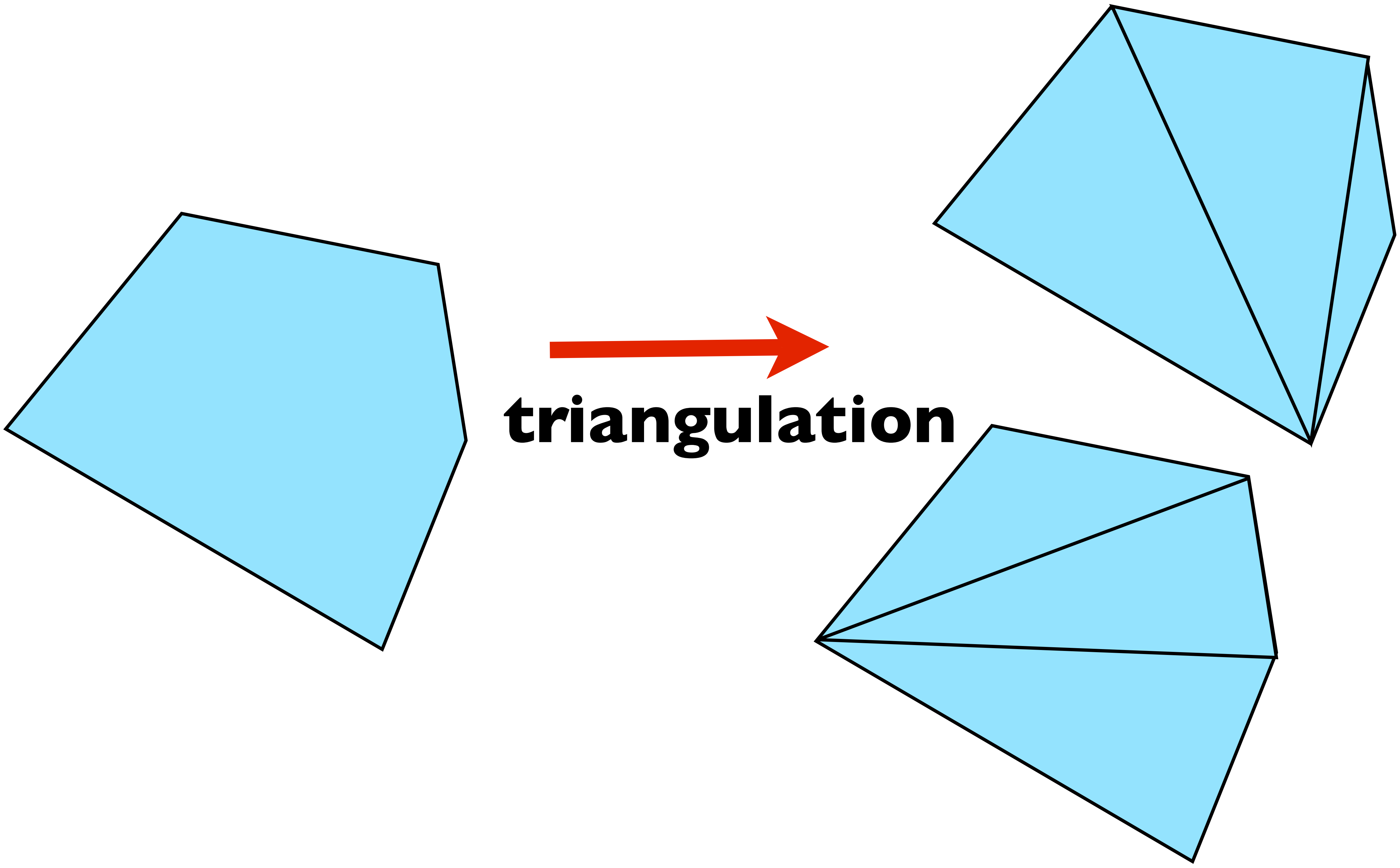


GL_TRIANGLE_STRIP



GL_TRIANGLE_FAN

Other polygons



triangulation
as long as triangles are not **collinear**, they will be **simple**, **flat,** and **convex -- easy to render**

Sample attributes

- Color glClearColor(1.0, 1.0, 1.0, 1.0);
- Point size glPointSize(2.0);
- Line width glLineWidth(3.0);