Ray Tracing

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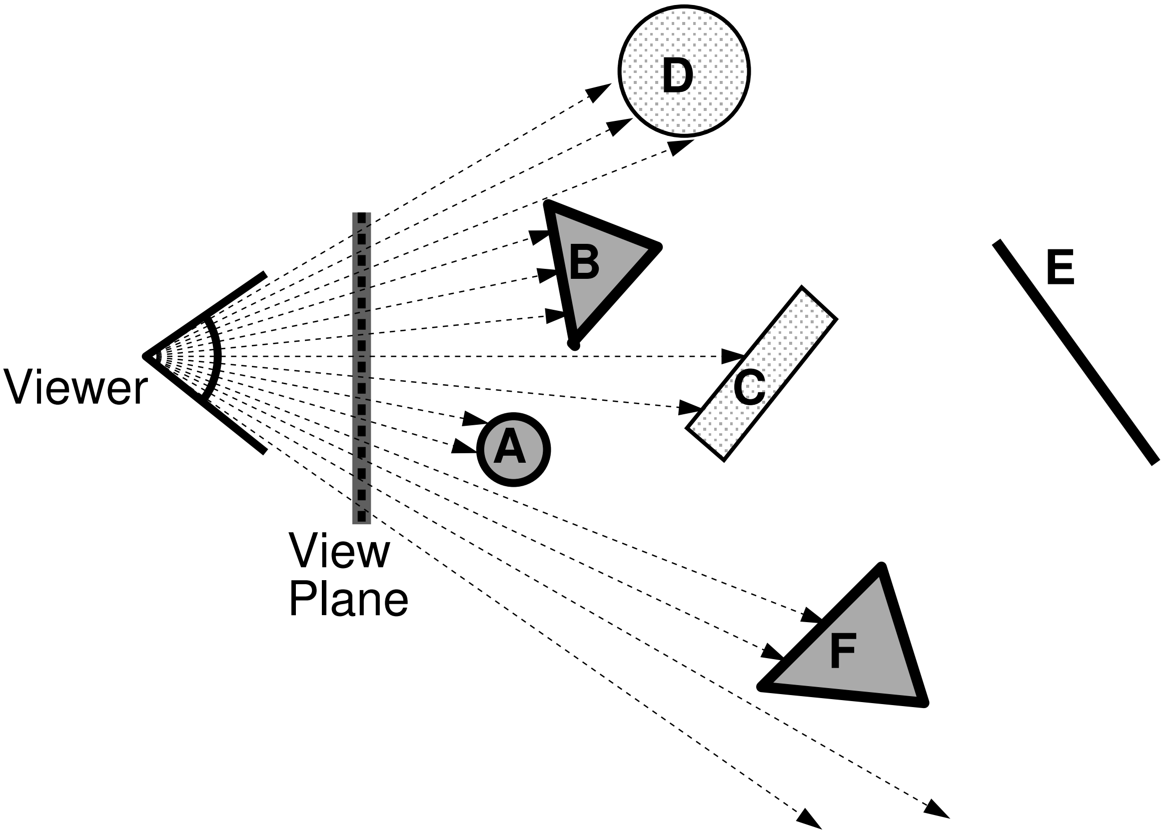
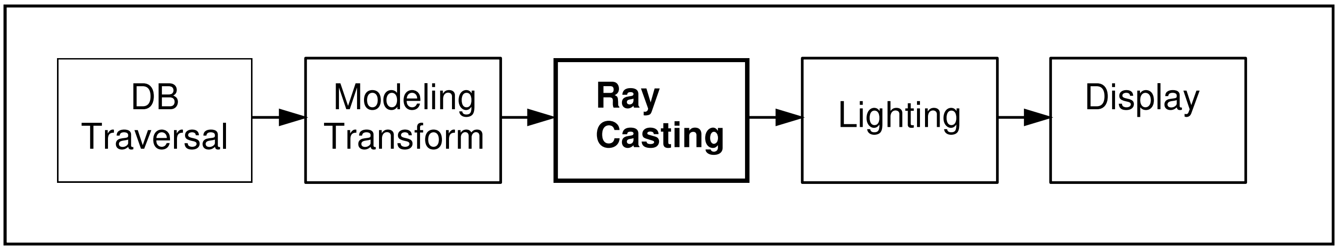
Overview

- Ray casting revisited
- Recursive ray tracing
- Ray–surface intersections
- Acceleration techniques
- Antialiased ray tracing

Ray Casting

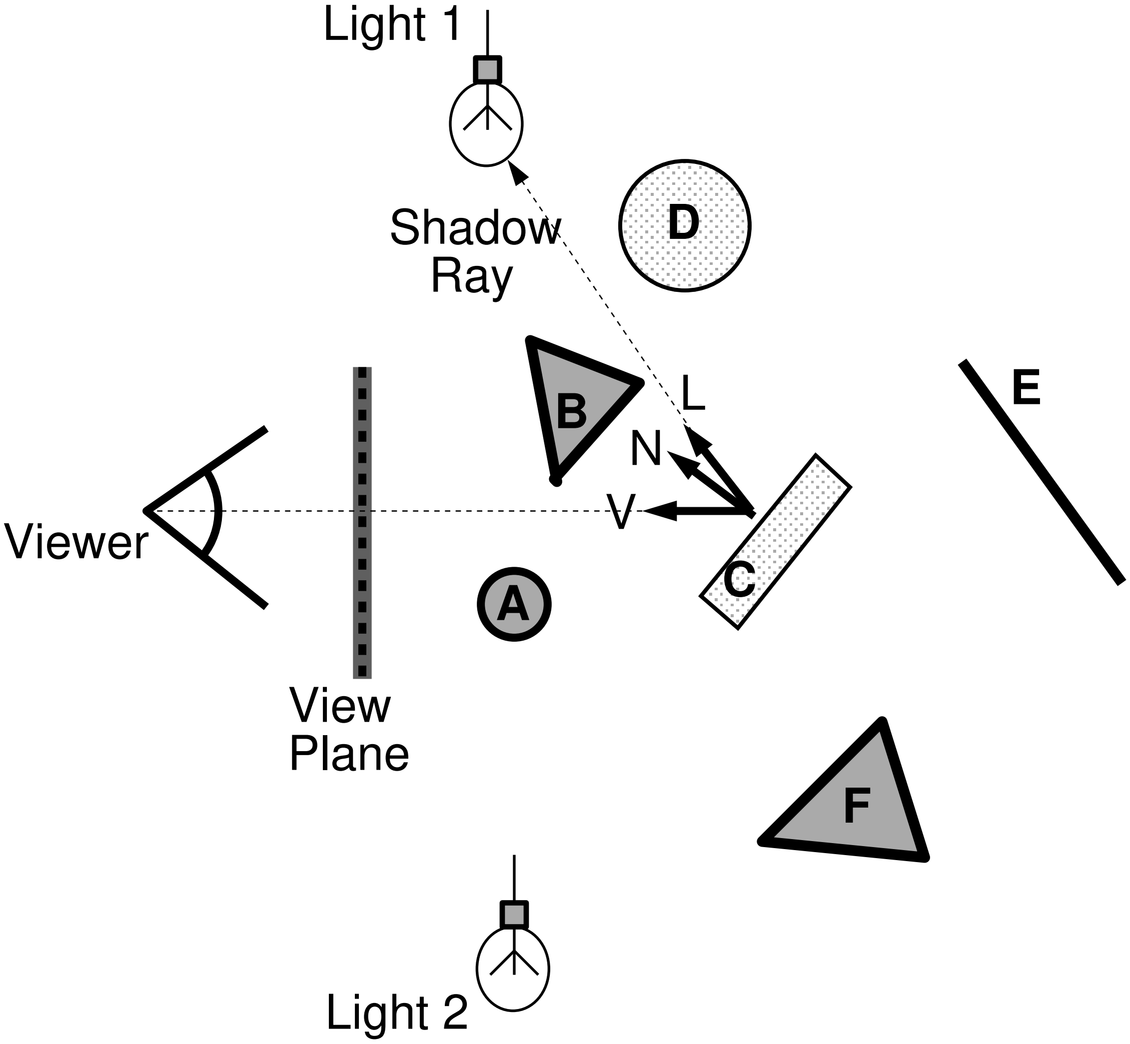


D
B
E
C
Viewer
A
View
Plane
F

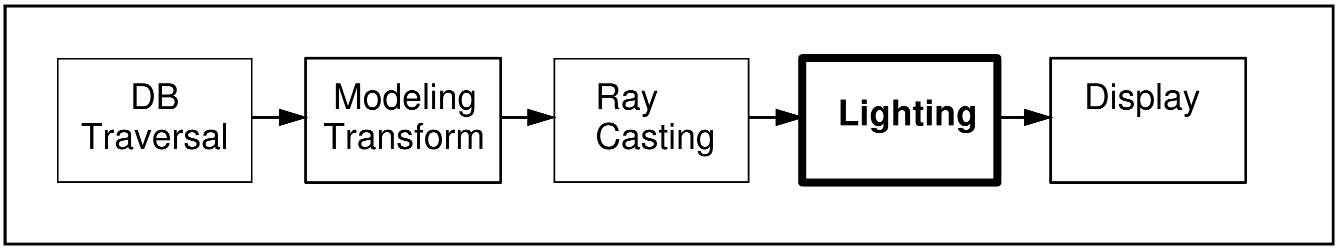


DB
Traversal
Modeling
Transform
Ray
Casting
Lighting
Display

Ray Casting



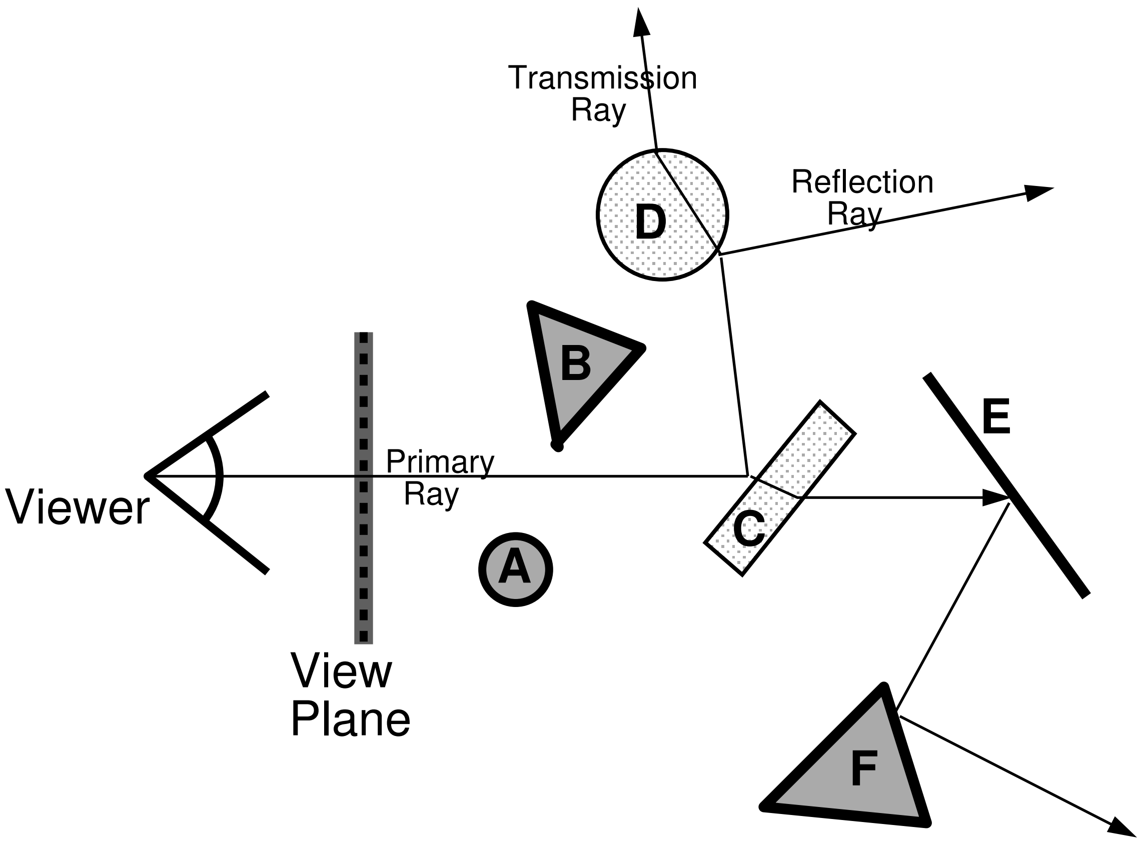
$$I = I_E + K_A I_A + \sum_{L_i} \left(K_D(N \bullet L_i) + K_S(V \bullet R_i)^n\right) S_i I_{L_i}$$

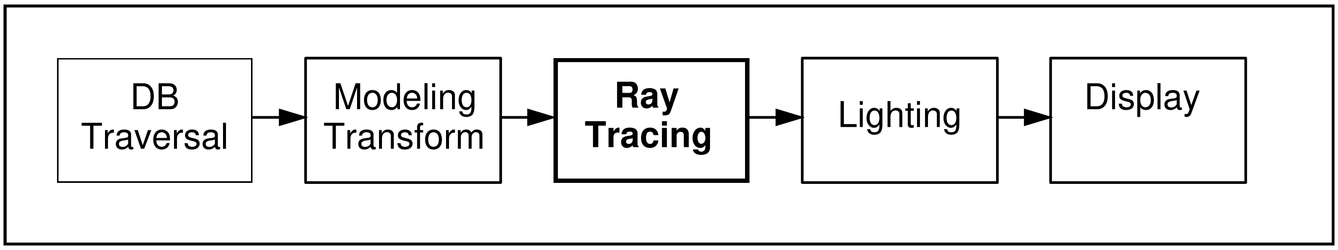


Ray Tracing

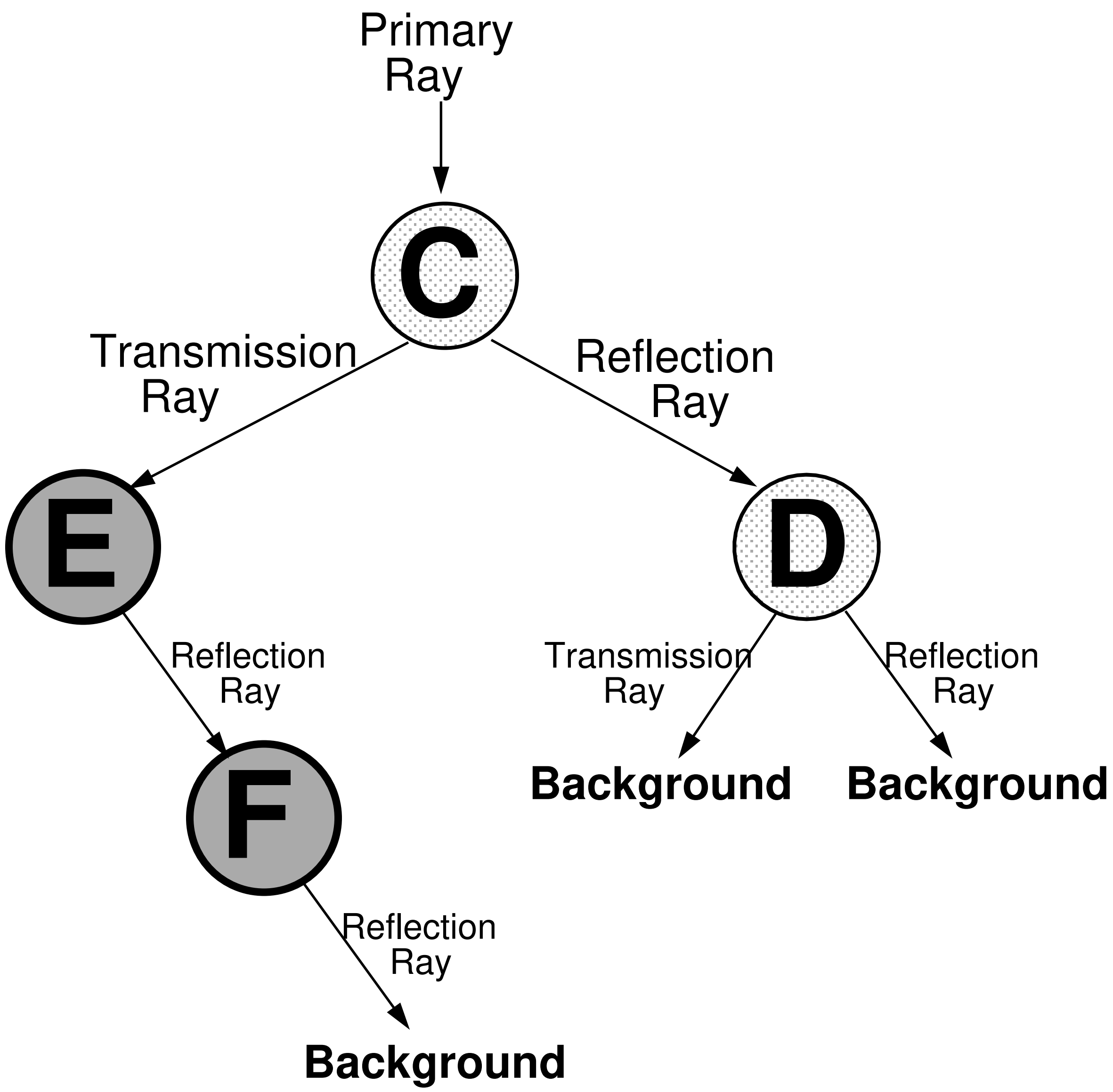
- ♦ **Goal**
  - – Simulate indirect illumination

Recursive Ray Tracing

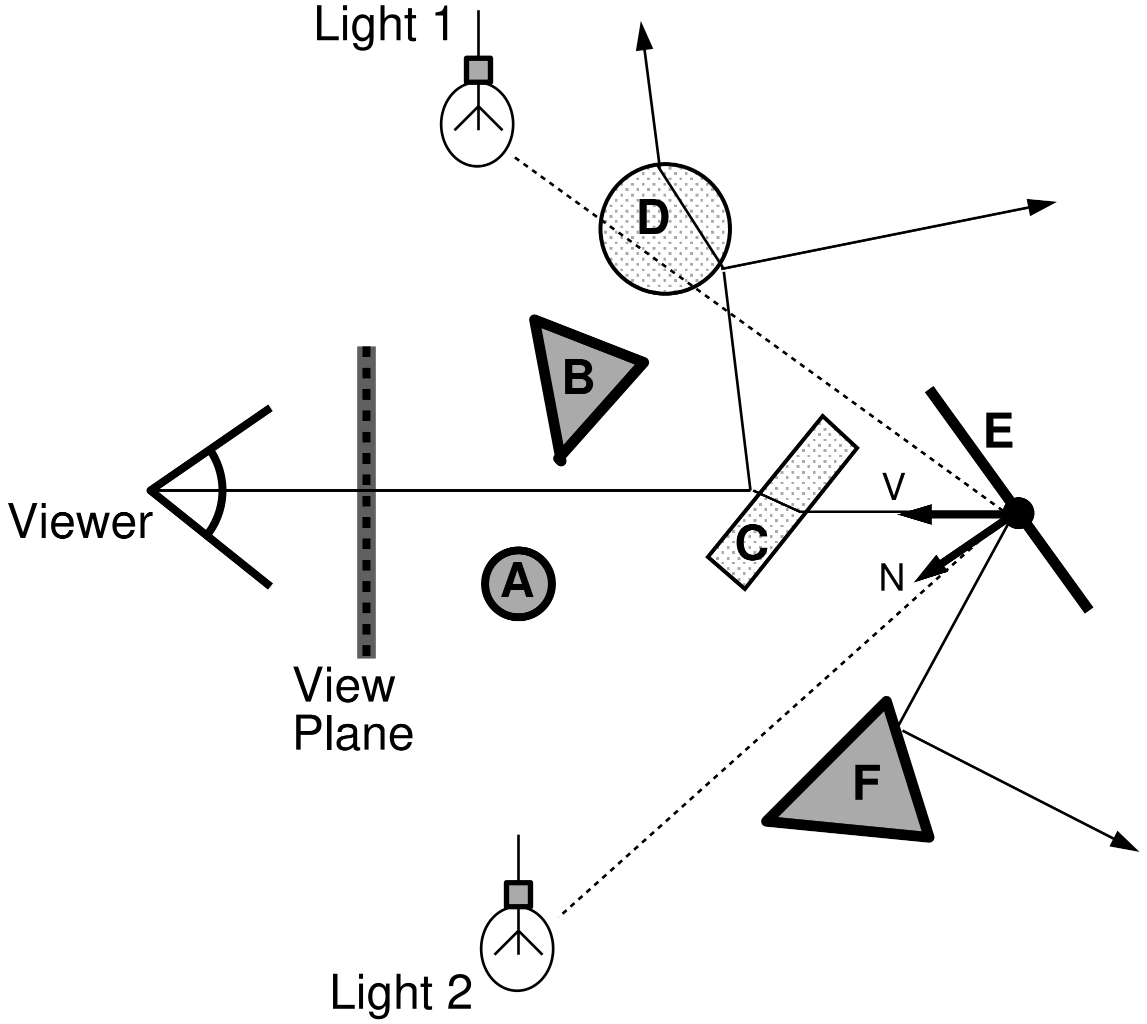




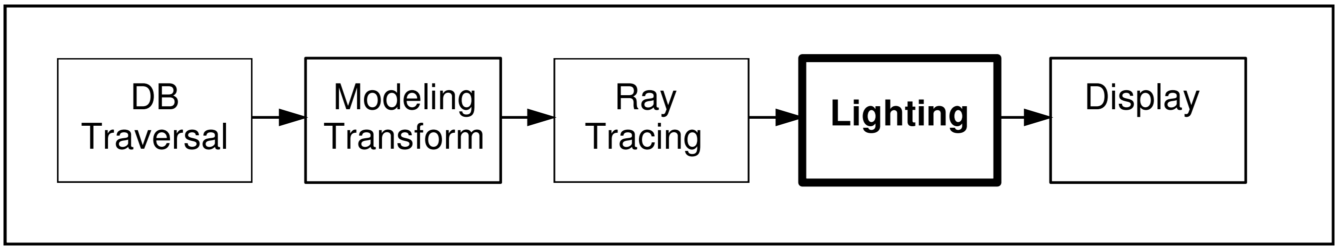
Ray Tracing Tree



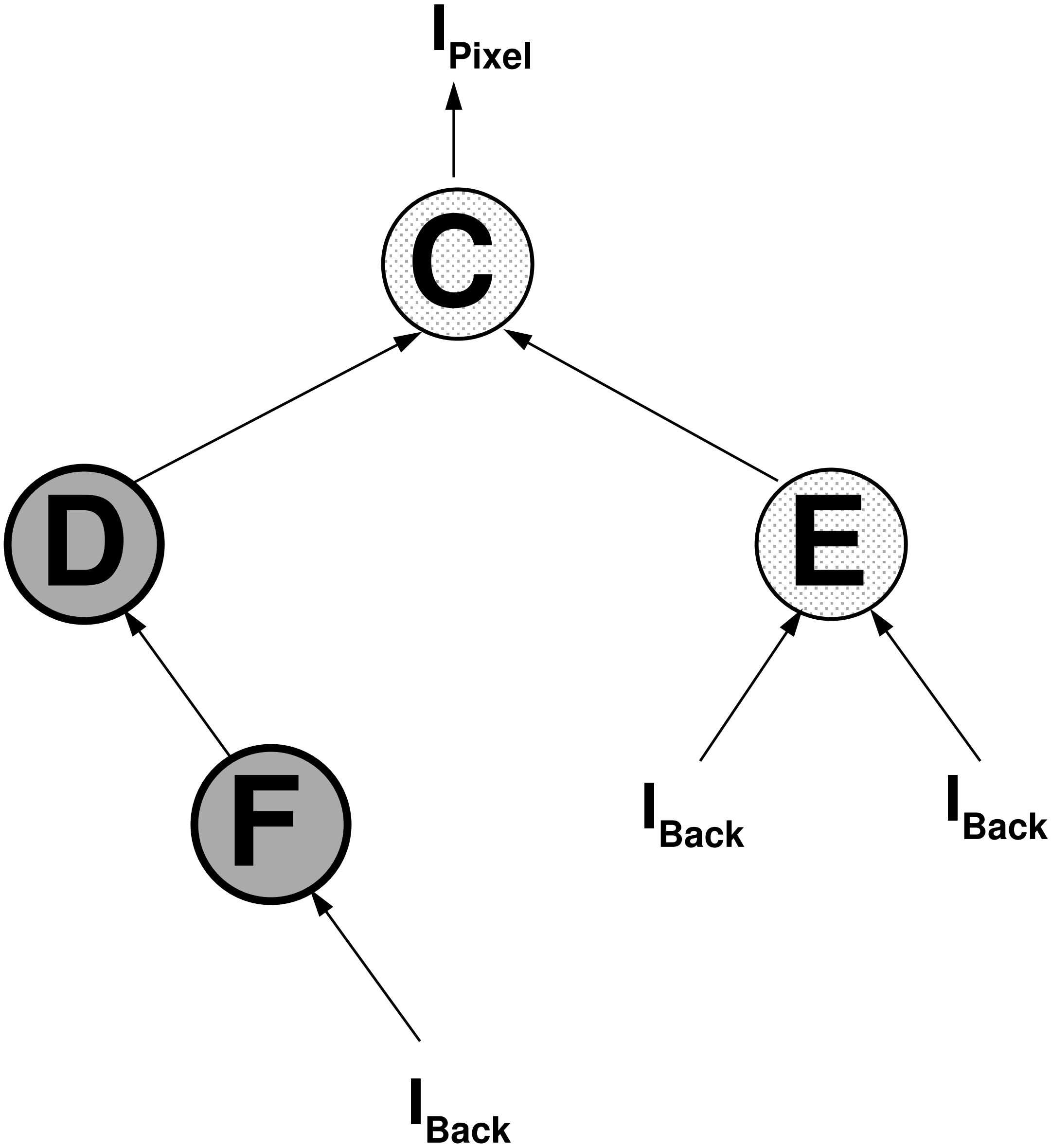
Ray Tracing Lighting



$$I=I_E+K_A I_A+\sum_{L_i}\left(K_D(N\bullet L_i)+K_S(V\bullet R_i)^n\right)S_i I_L+K_S I_R+K_T I_T$$



Ray Tracing Lighting



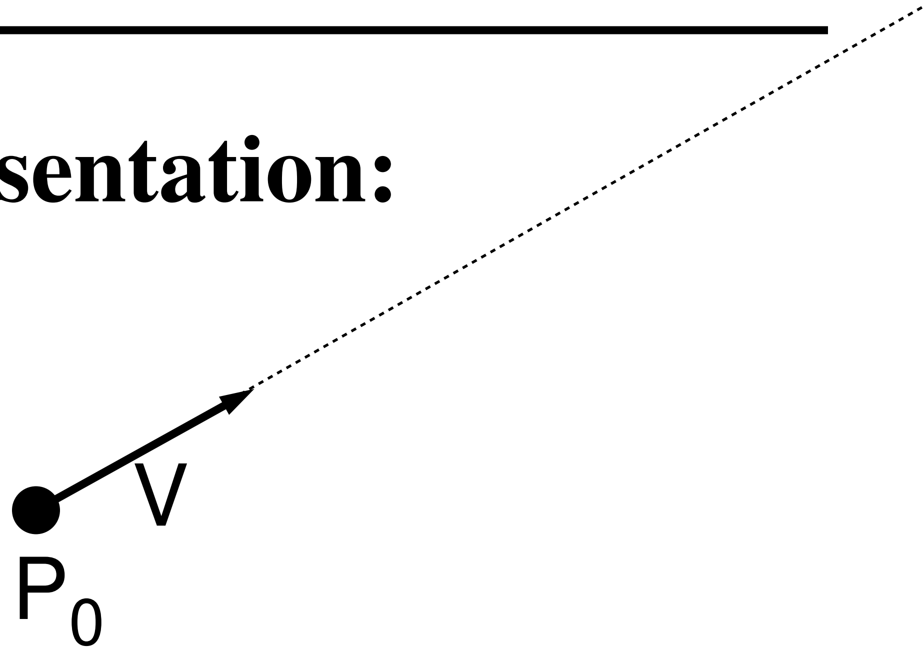
$$I = I_E + K_A I_A + \sum_{L_i} \left(K_D (N \bullet L_i) + K_S (V \bullet R_i)^n \right) S_i I_L + K_S I_R + K_T I_T$$

Ray Intersections

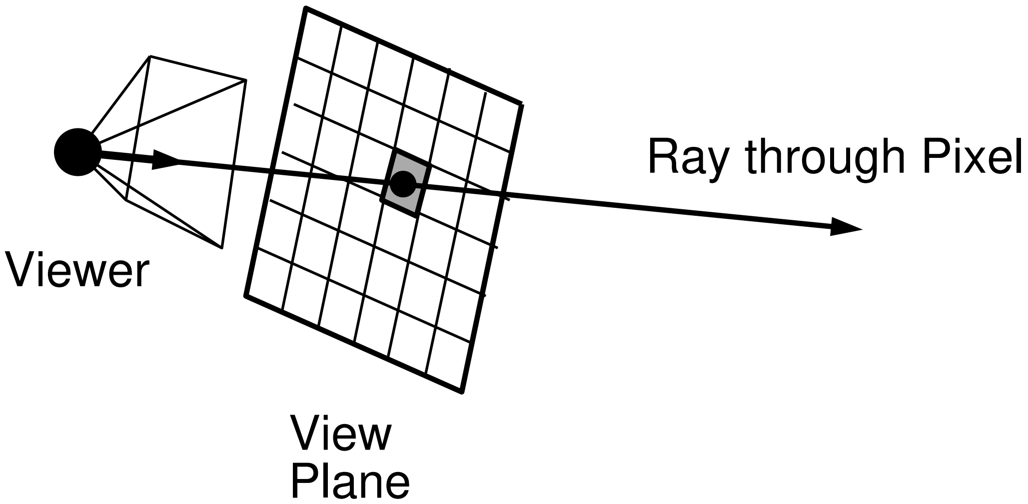
- **Ray representation:**

$P = P_0 + tV$

$t >= 0$



- **Ray through a pixel:**



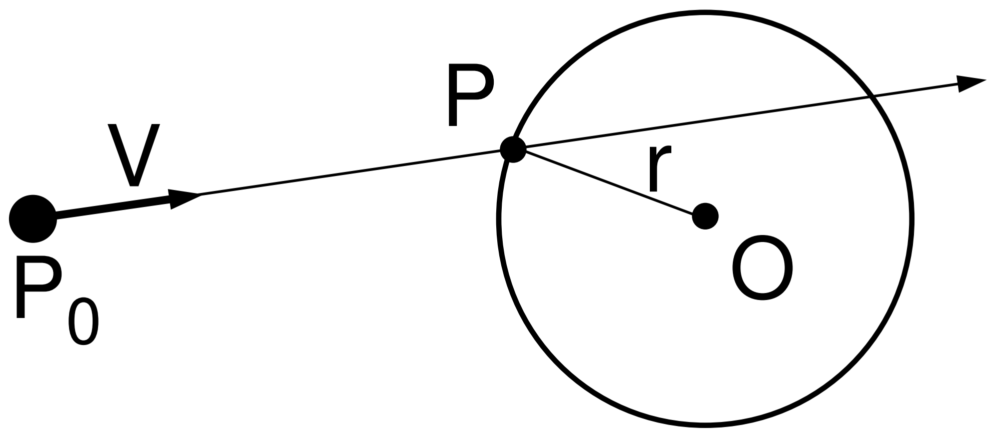
Ray–Sphere Intersection

- **Algebraic solution:**

Ray: $P = P_0 + tV$
Sphere: $|P - O|^2 - r^2 = 0$

substitute: $|\mathbf{P_0 + tV} - O|^2 - r^2 = 0$

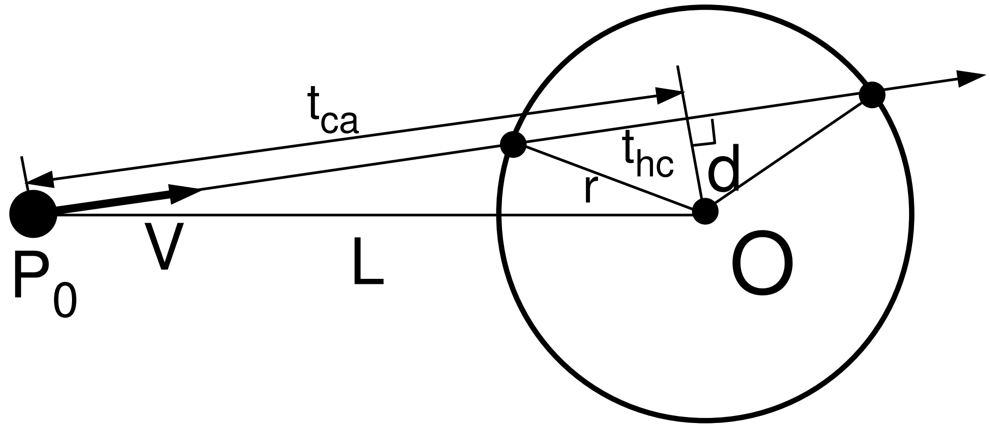
solve $At^2 + Bt + C = 0$
where $A = 1$
$B = 2\, V \bullet (P_0 - O)$
$C = |P_0 - O|^2 - r^2$



Ray–Sphere Intersection

- **Geometric solution:**

$$L = O - P_0$$
$$t_{ca} = L \bullet V$$
$$\text{if } (t_{ca} < 0) \text{ then no intersection}$$
$$d = L \bullet L - t_{ca}^2$$
$$t_{hc} = \mathrm{sqrt}(r^2 - d^{2)}$$
$$\text{if } (t_{hc} < 0) \text{ then no intersection}$$
$$t = t_{ca} - t_{hc} \text{ AND } t_{ca} + t_{hc}$$

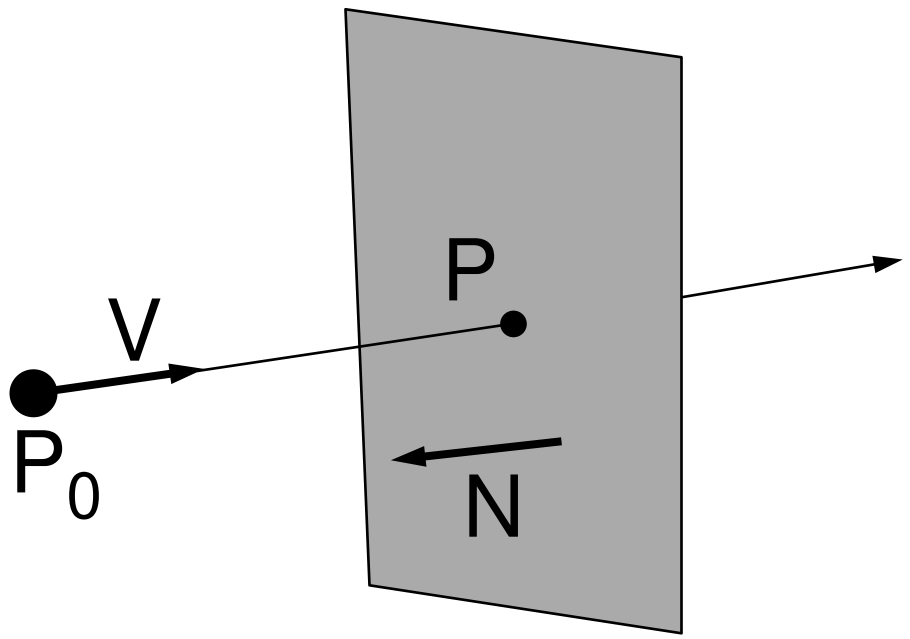


Ray–Plane Intersection

Ray: $P = P_0 + tV$
Plane: $P \bullet N + D = 0$

substitute: $(\mathbf{P_0 + tV}) \bullet N + D = 0$

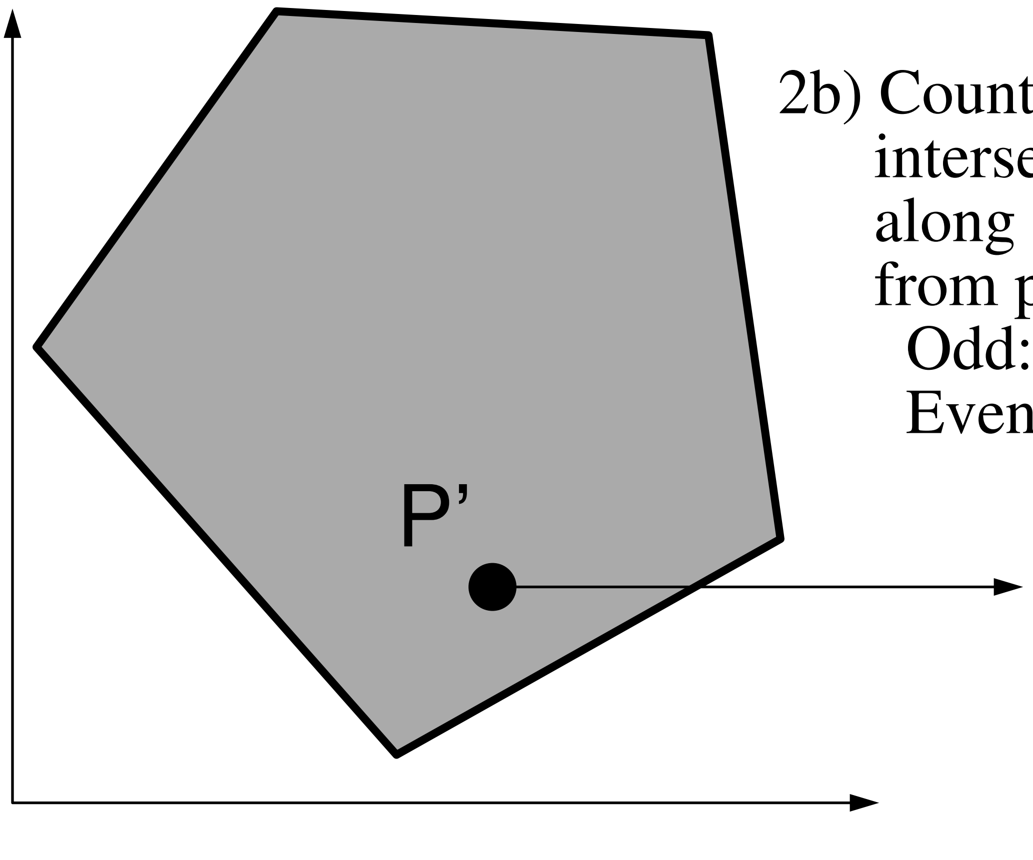
solution: $t = -(P_0 \bullet N + D) / (V \bullet N)$



Ray–Polygon Intersection

1) P = ray–plane intersection

2) Check if polygon contains P

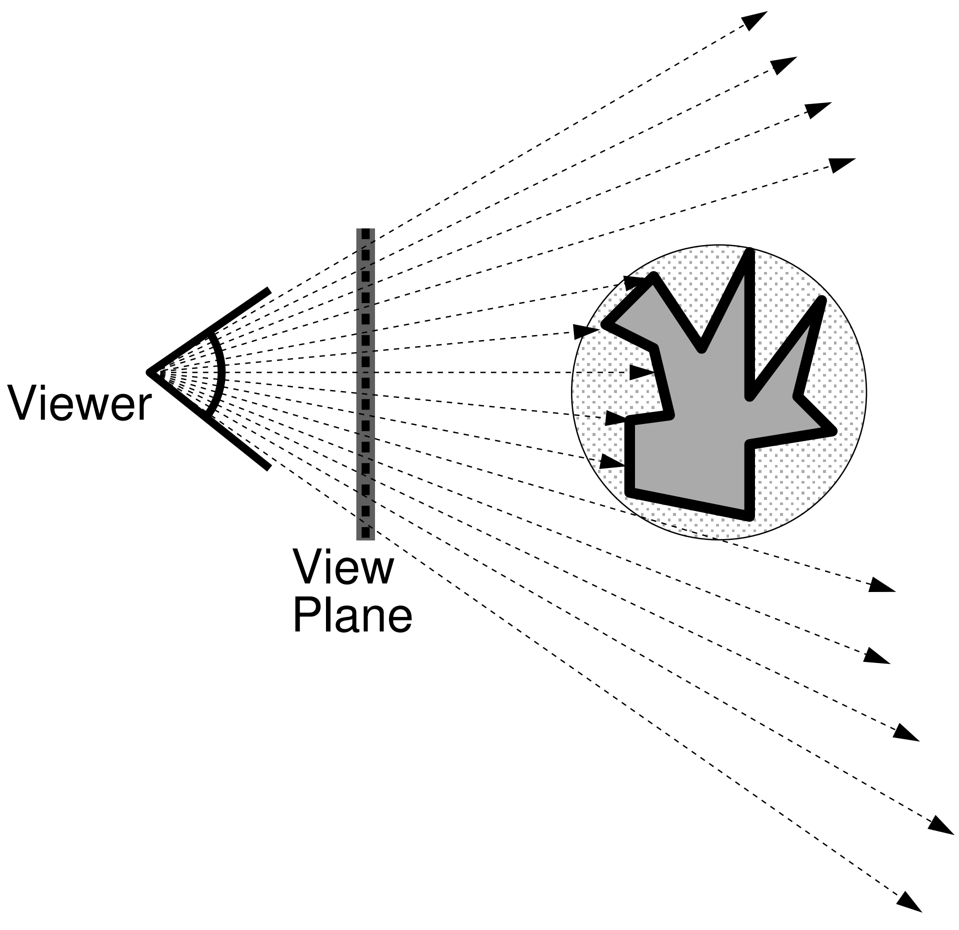


2a) Project P
to P' in 2D

2b) Count edge
intersections
along any ray
from point:
Odd: inside
Even: outside

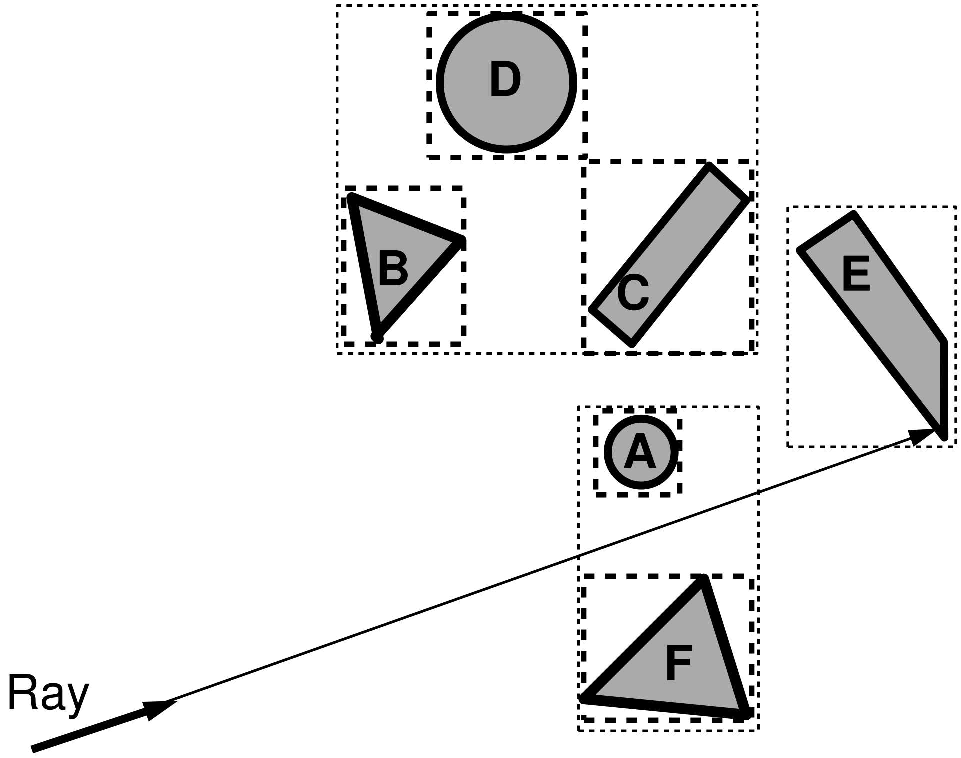
Ray Tracing Acceleration

- **Bounding volumes**
  - Check simple bounding volume for ray–surface intersections before checking complex shapes



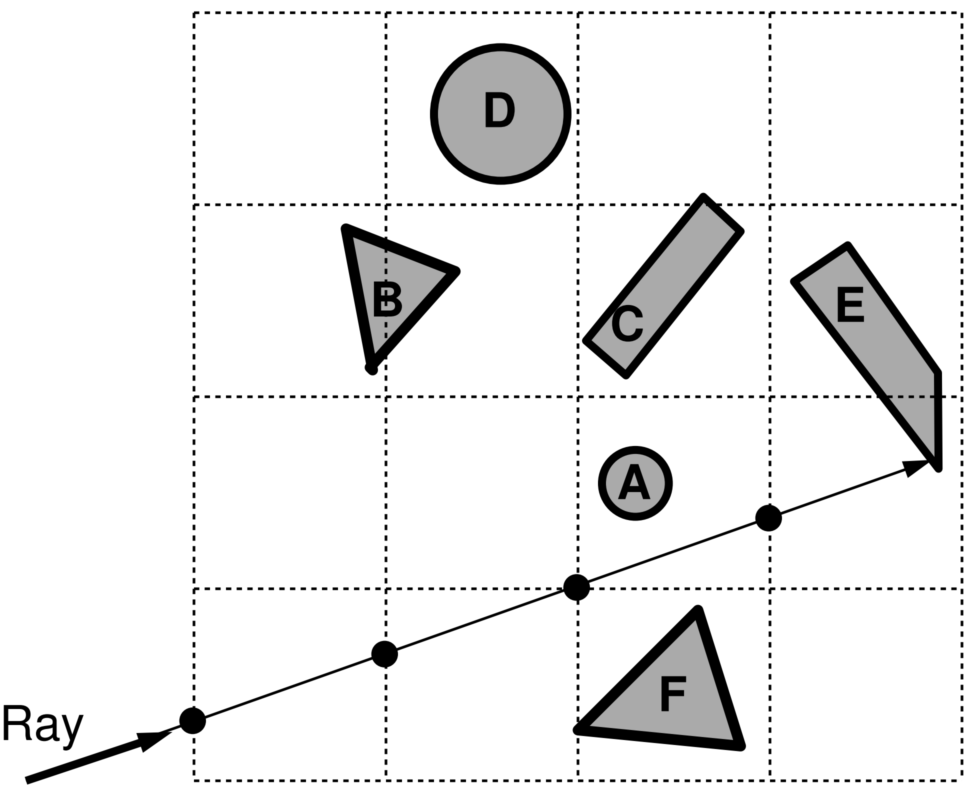
Ray Tracing Acceleration

- **Bounding volume hierarchies**
  - Construct and check hierarchical bounding volumes



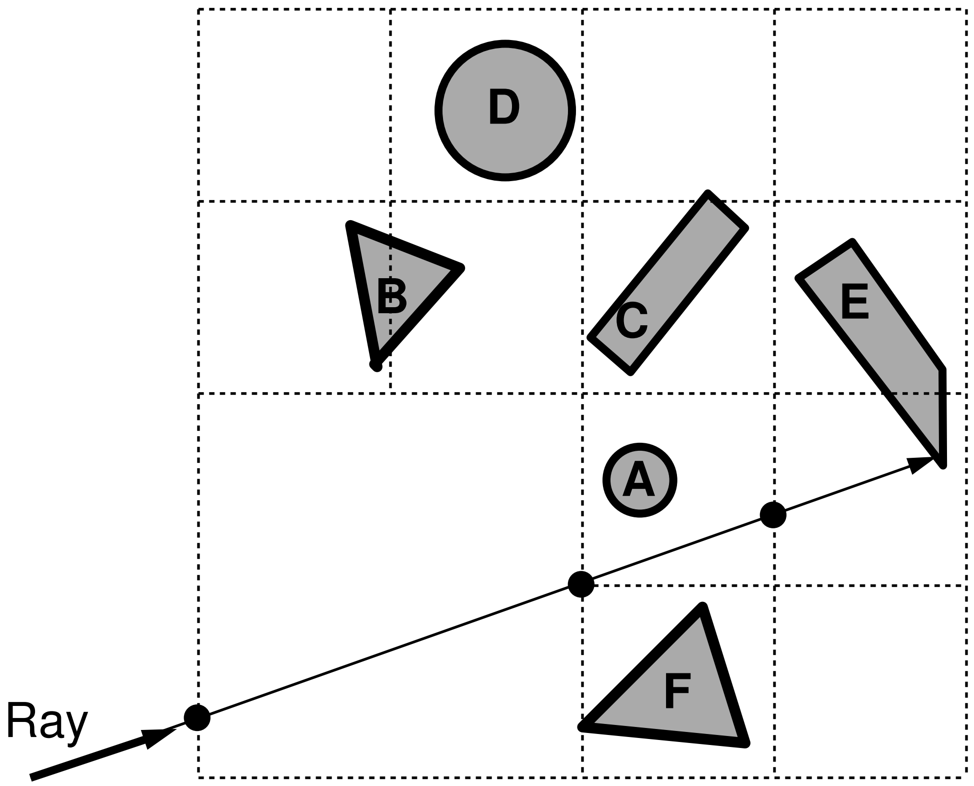
Ray Tracing Acceleration

- **Spatial data structures**
  - Uniform Grids:



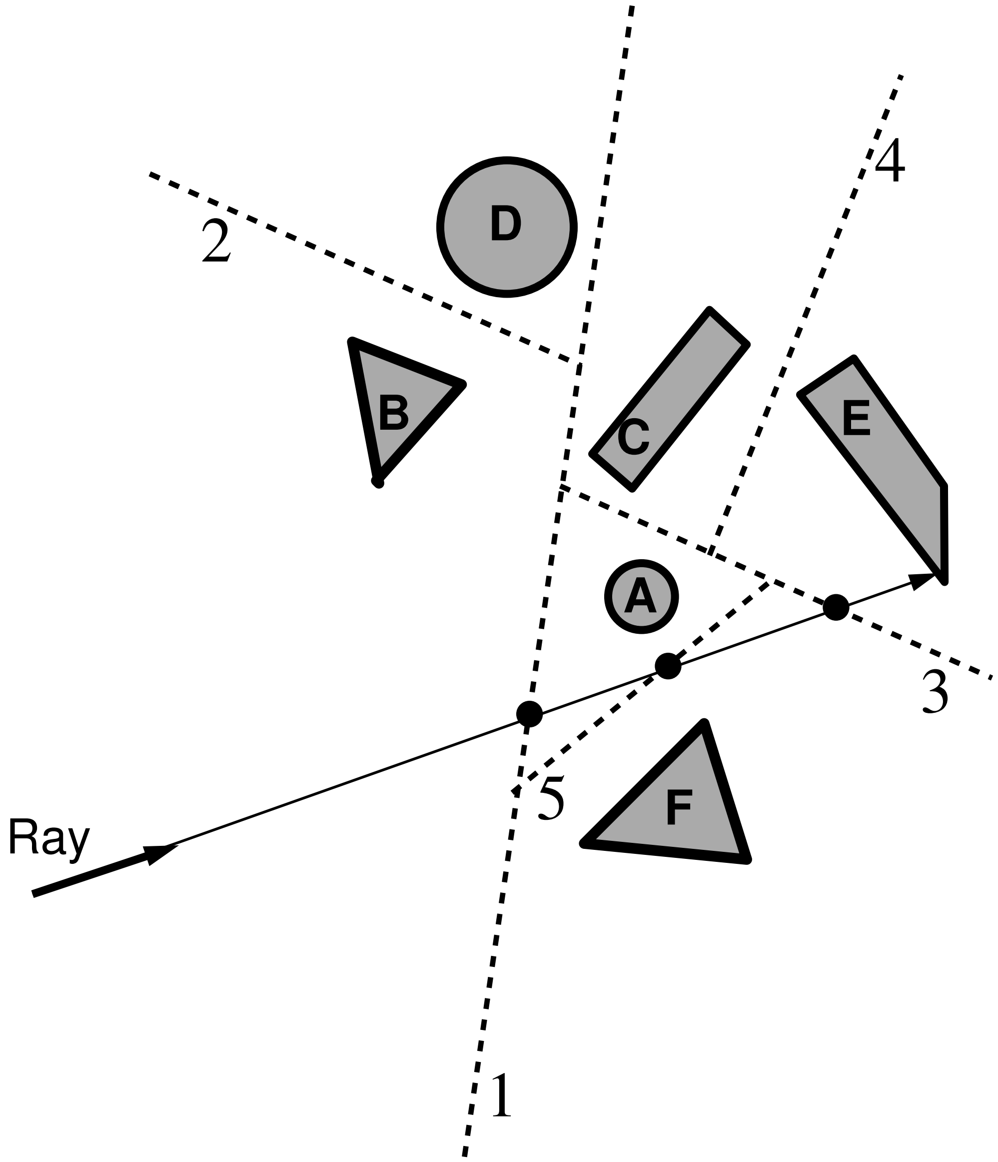
Ray Tracing Acceleration

- **Spatial data structures**
  - Octrees:



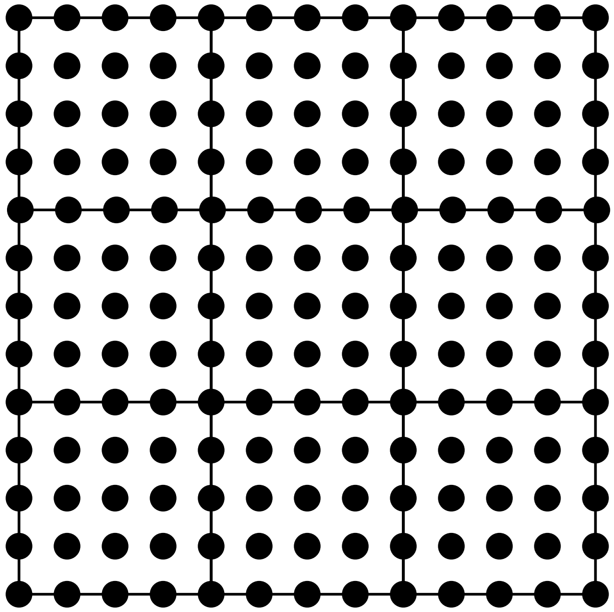
Ray Tracing Acceleration

- **Spatial data structures**
  - BSP trees:

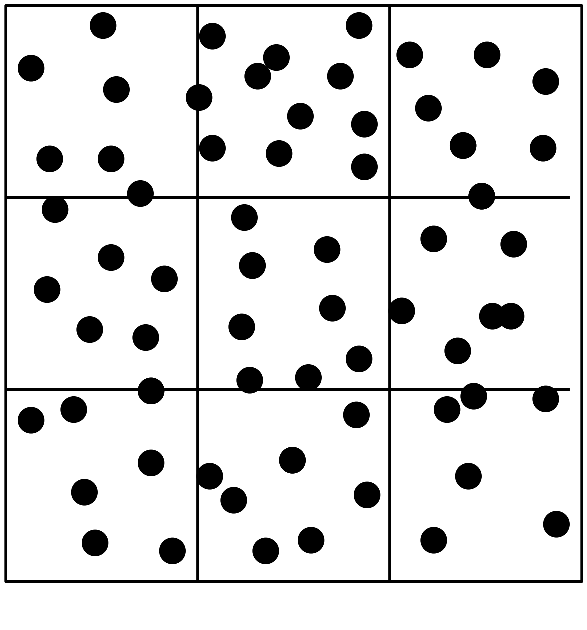


Antialiasing

- **Supersampling**
  – Multiple, evenly spaced samples per pixel



- **Adaptive sampling**
  – Randomized, directed samples



Summary

- Ray casting
- Recursive ray tracing
- Ray trees
- Ray–surface intersections
- Spatial Subdivisions
- Antialiasing