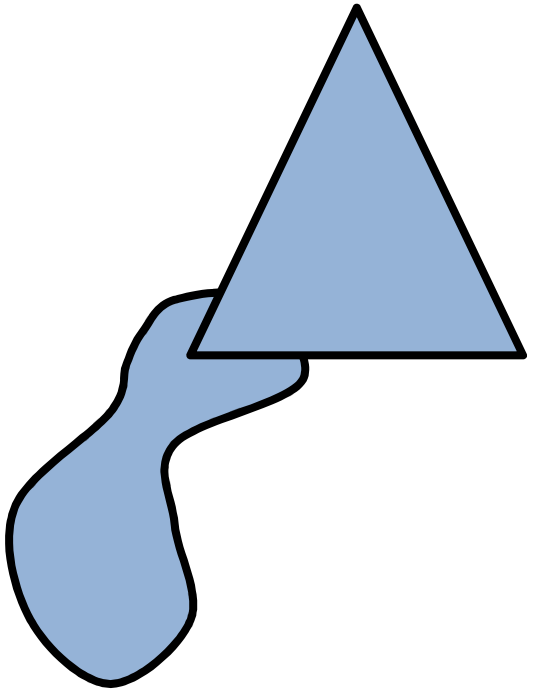
Collision Detection

Why?

- Realisme
  - Without ”quantum effects”
    - Objects pass through other objects
- Game play

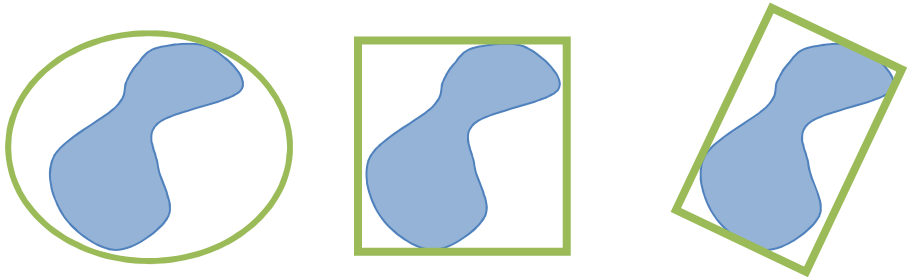
Three Major Parts

- Collision detection
  - Do the objects collide?
- Collision determination
  - Where do they collide?
- Collision response
  - What happens now?



Phases

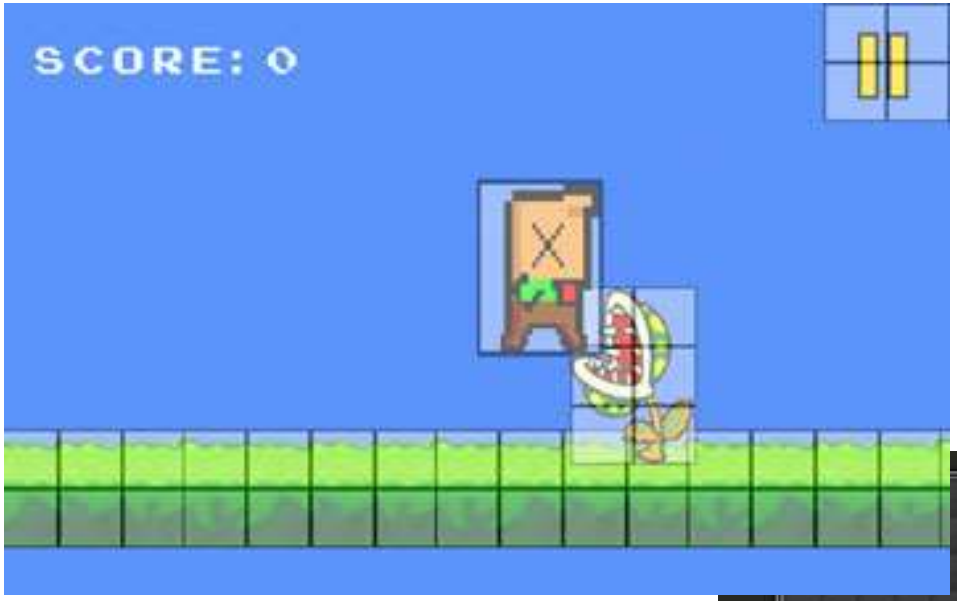
- Broad Phase (use placeholder geometry for speed)
  - Grids
  - Bounding Spheres
  - AABB-Algorithm
  - OBB-Algorithm
  - Subdivisions

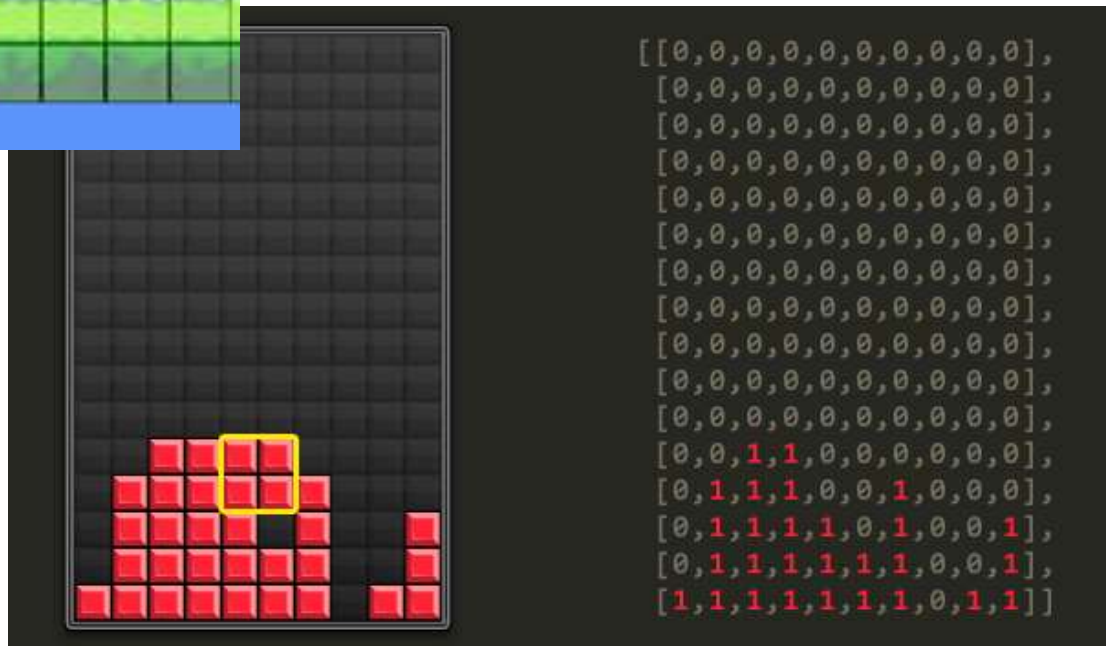


- Narrow Phase (real object is intersected)
  - Point-Line
  - Point-Triangle
  - Triangle-Triangle
  - …

Broad Phase

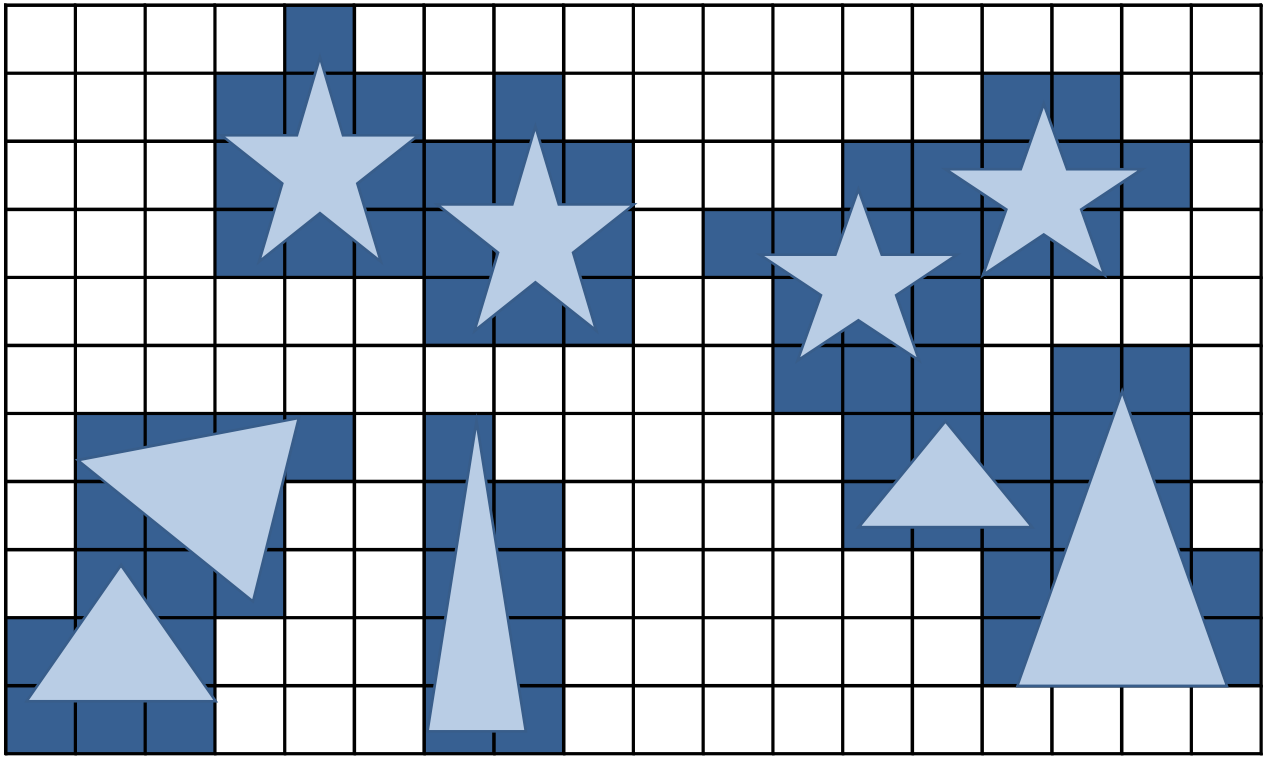
Regular Subdivision



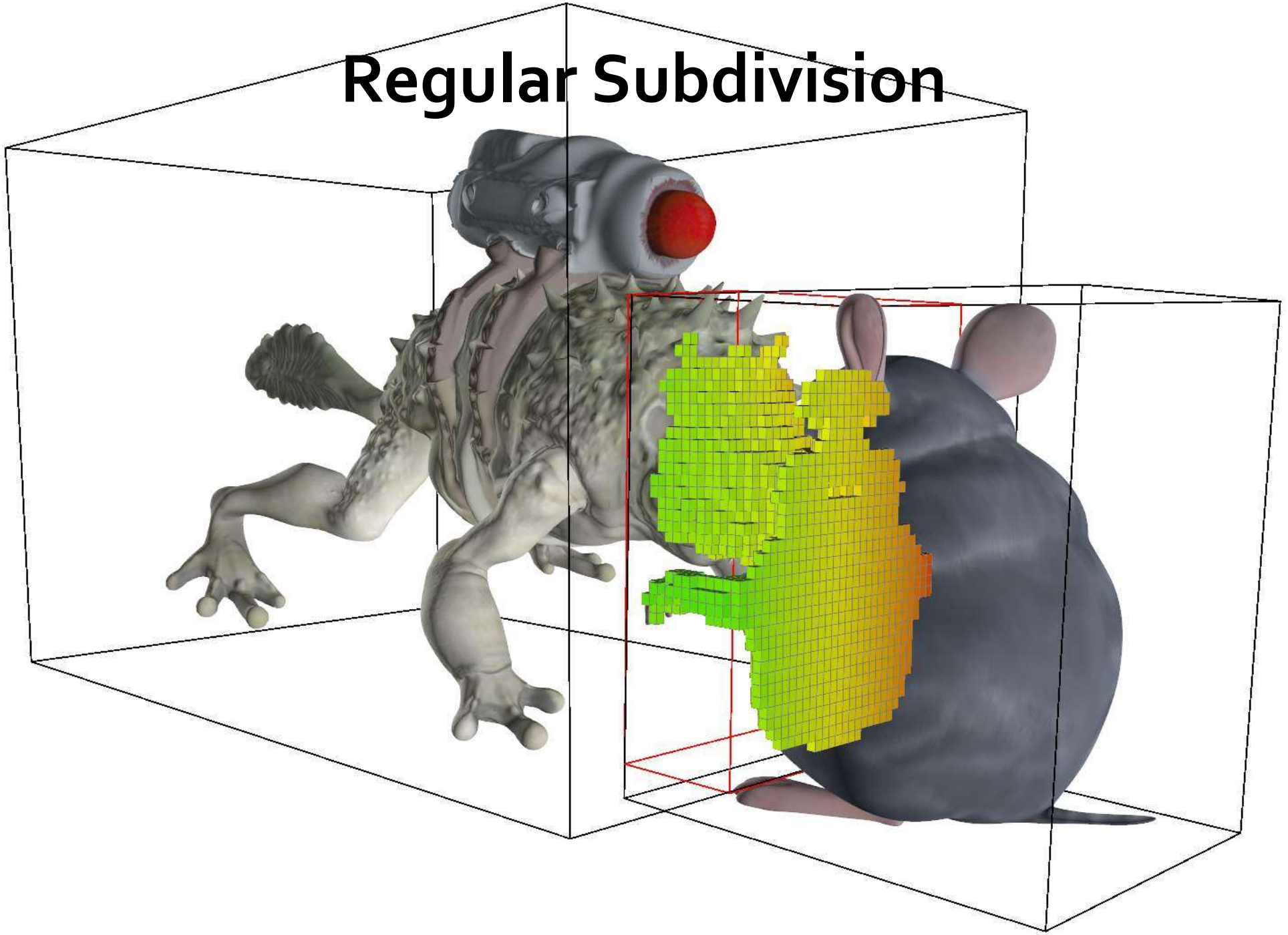


Regular Subdivision

- Test with regular grid

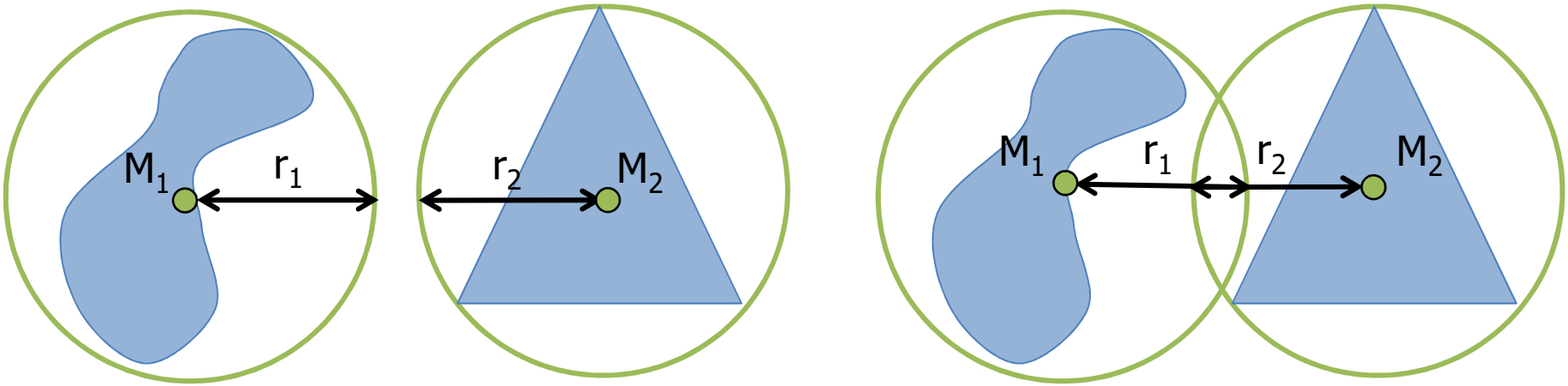


Regular Subdivision



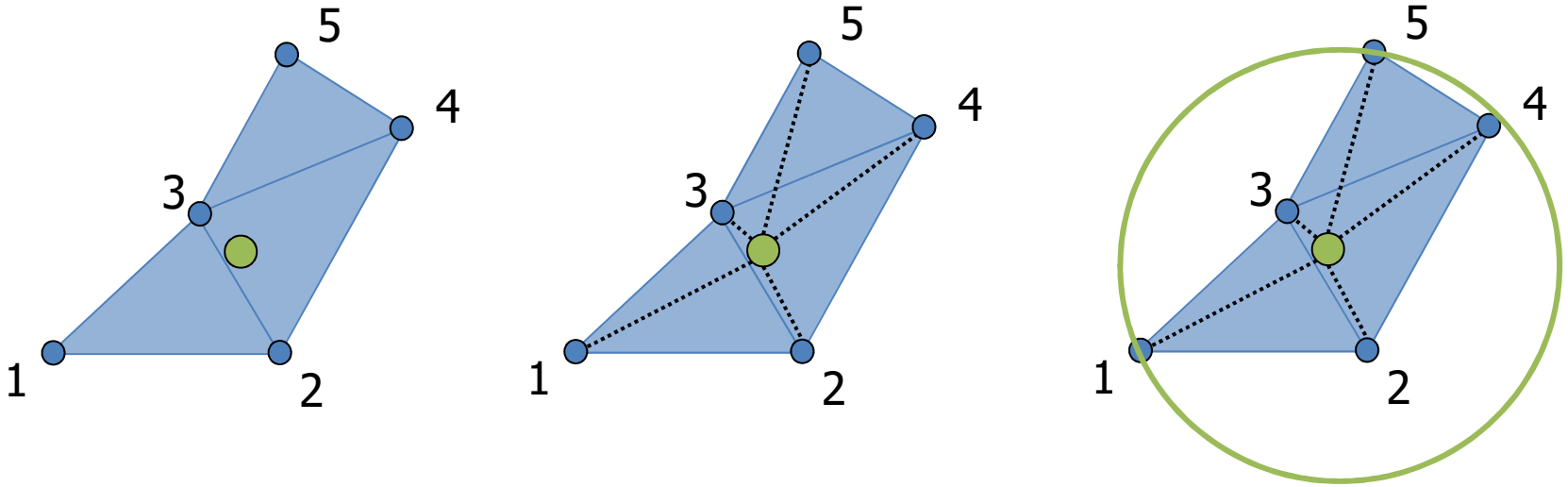
Bounding Spheres

- Collision if $distance(M_1, M_2)^2 < (r_1 + r_2)^2$



Calculating Bounding Spheres

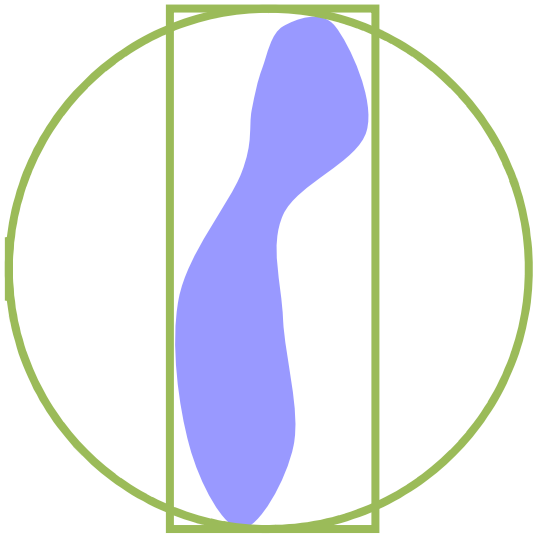
- Find the center
  - Average of all vertices
- Find radius
  - For all vertices: calculate max. distance to M
- In mathematics: minimal bounding sphere problem

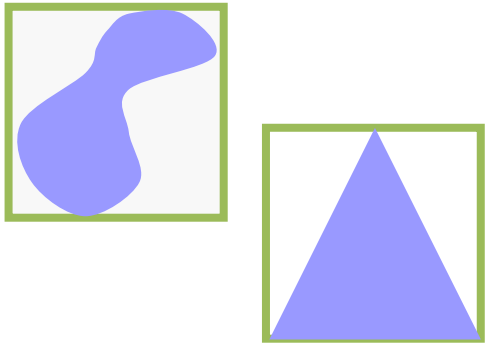


Creative Use of Bounding Spheres

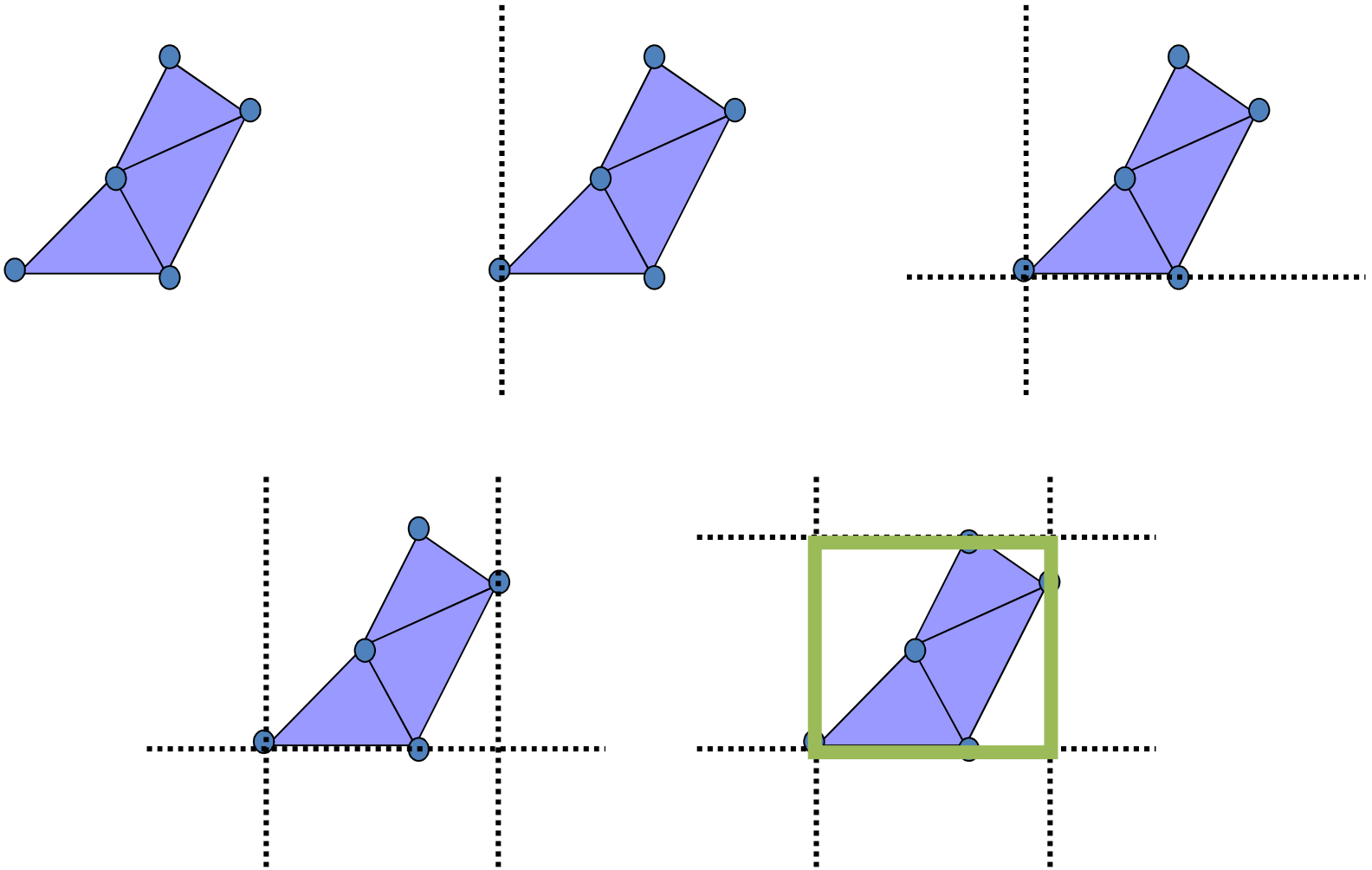
AABB-Algorithm

- Bounding-Spheres:
  - Efficient
  - Inaccurate
- Axis Aligned Bounding Boxes
  - Better Fit
  - Only slightly more complicated



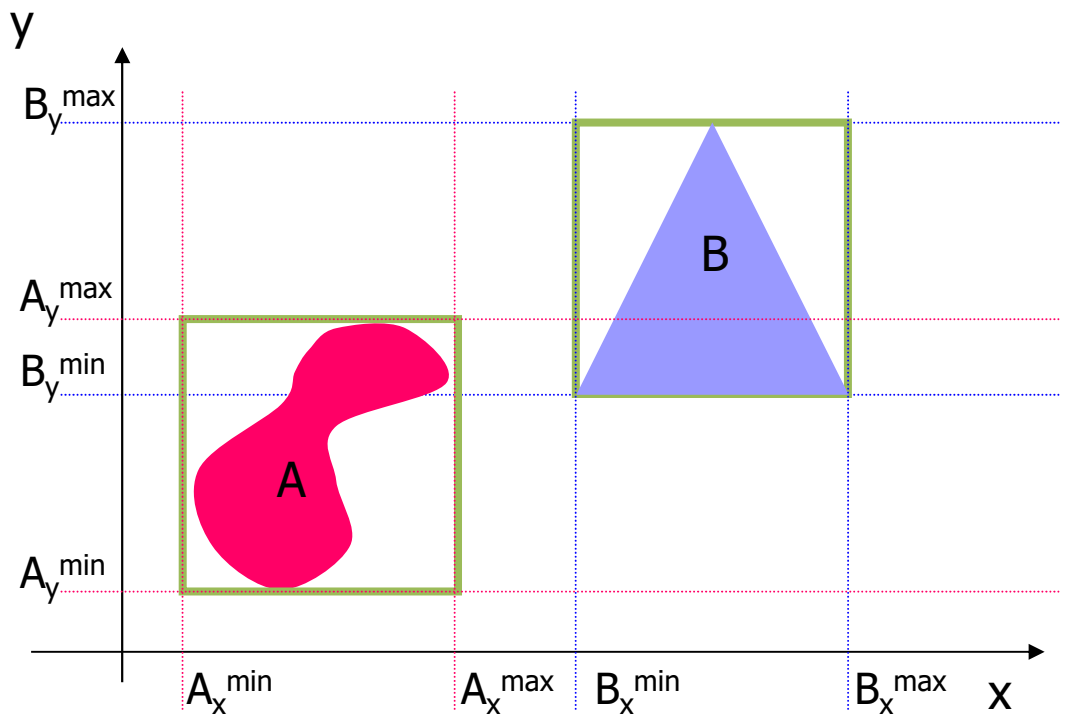


AABB-Algorithm



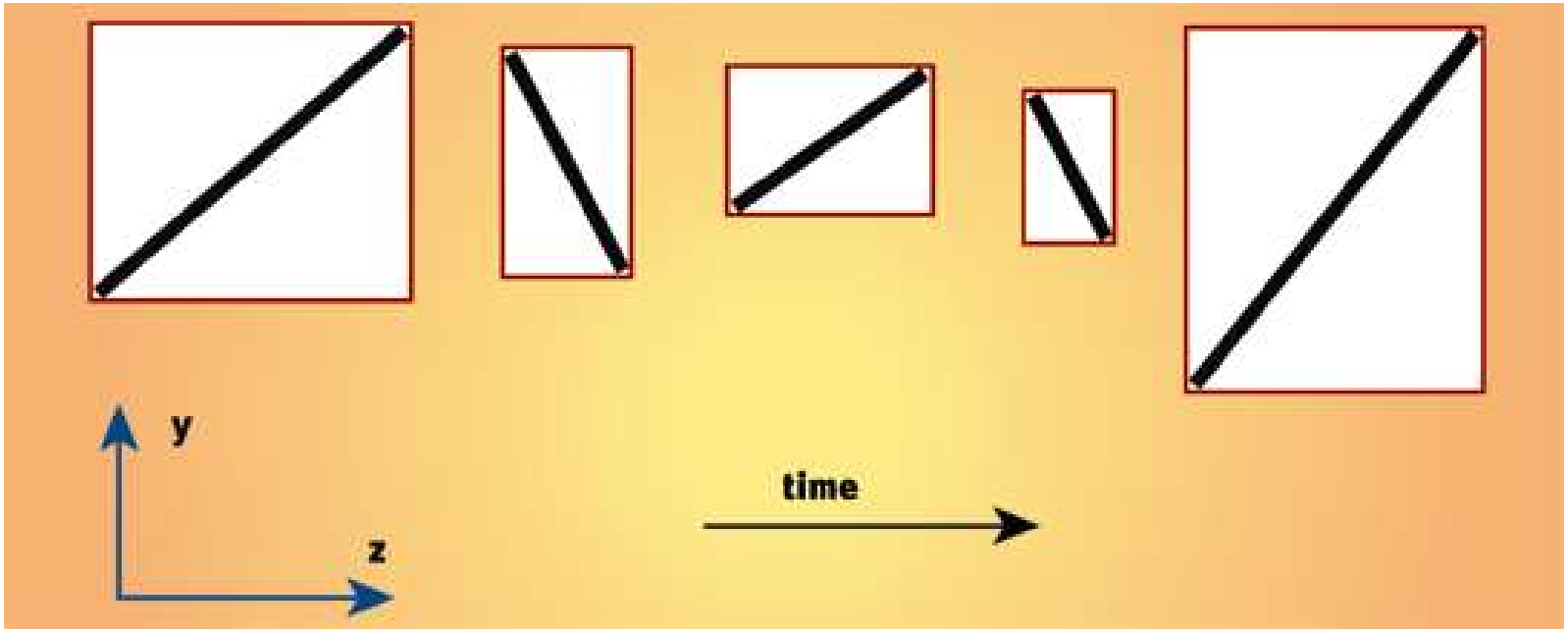
AABB-Algorithm

- No collision if
- $\exists i \in \{x, y, z\} | \left(\mathrm{A}_i^{min} > \mathrm{B}_i^{max} \right) or \left(\mathrm{B}_i^{min} > \mathrm{A}_i^{max} \right)$
  - Separating axis theorem



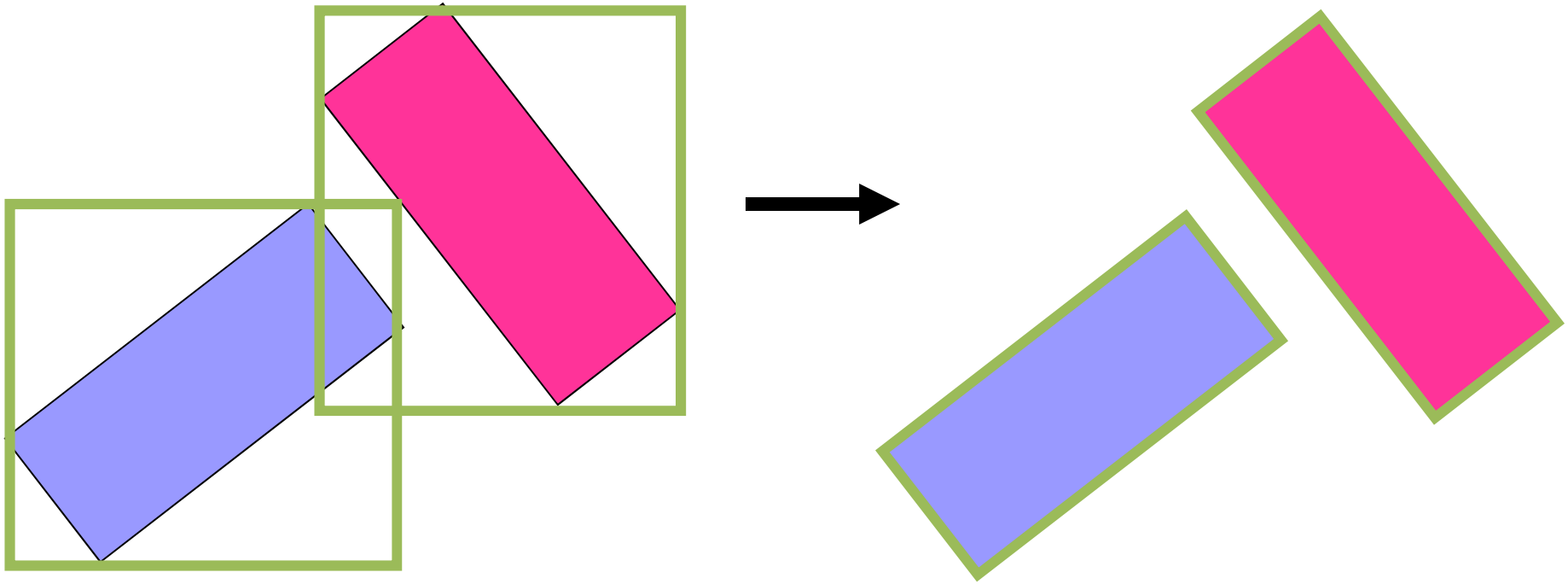
AABB - Problems

- While rotating an object, we have to recalculate the bounding box



Oriented Bounding Box

- Which problems do we have using the AABB approach?
  - *SIGGRAPH 1996, Gottschalk et al.*

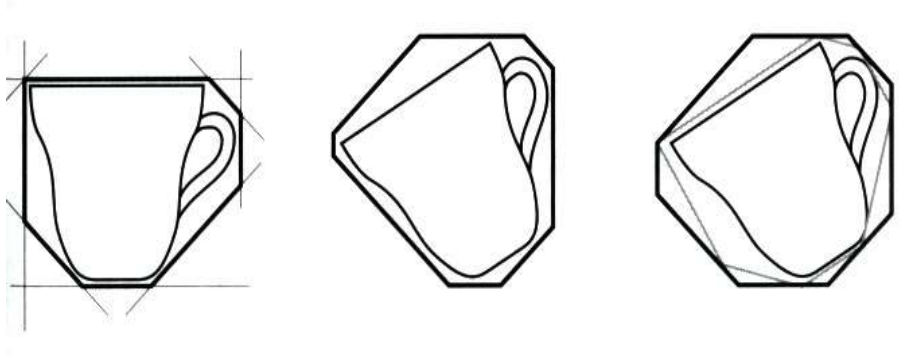


Oriented Bounding Box

- Rotation is no further a problem
- 95% of the situations are solved
- More complicated to calculate than AABB
- Separating axis theorem still works
- More math involved
- Find more information under
  - www.gamasutra.com
  - Game Programming Gems (I, II, III)

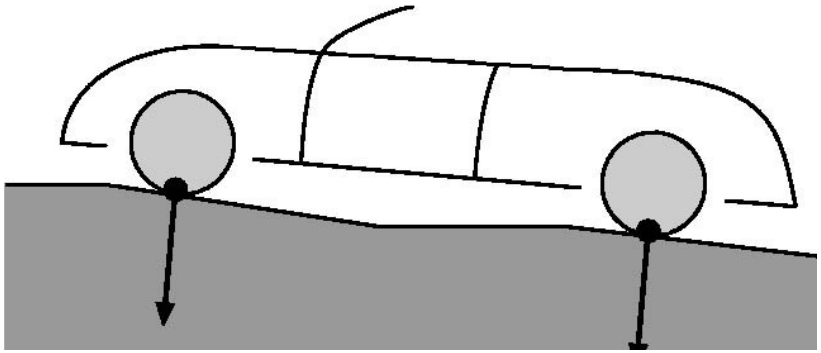
k-DOP

- k-Discrete Oriented Polytop
- OBB and AABB are 6-DOPs
- Optimal bounding boxes



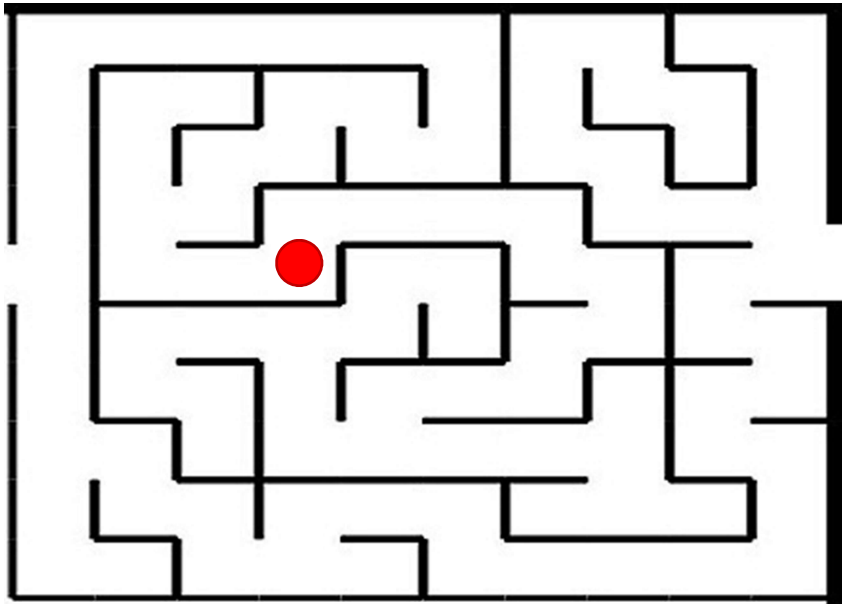
Collision Detection with Rays

- E.x.: car on road, player on terrain
- Test all triangles of all wheels against road geometry
- Often approximation good enough
- Idea: approximate complex object with set of rays



Another Simplification

- Sometimes 3D can be turned into 2D operations
- Example: maze
- Approximate player by circle
- Test circle against lines of maze



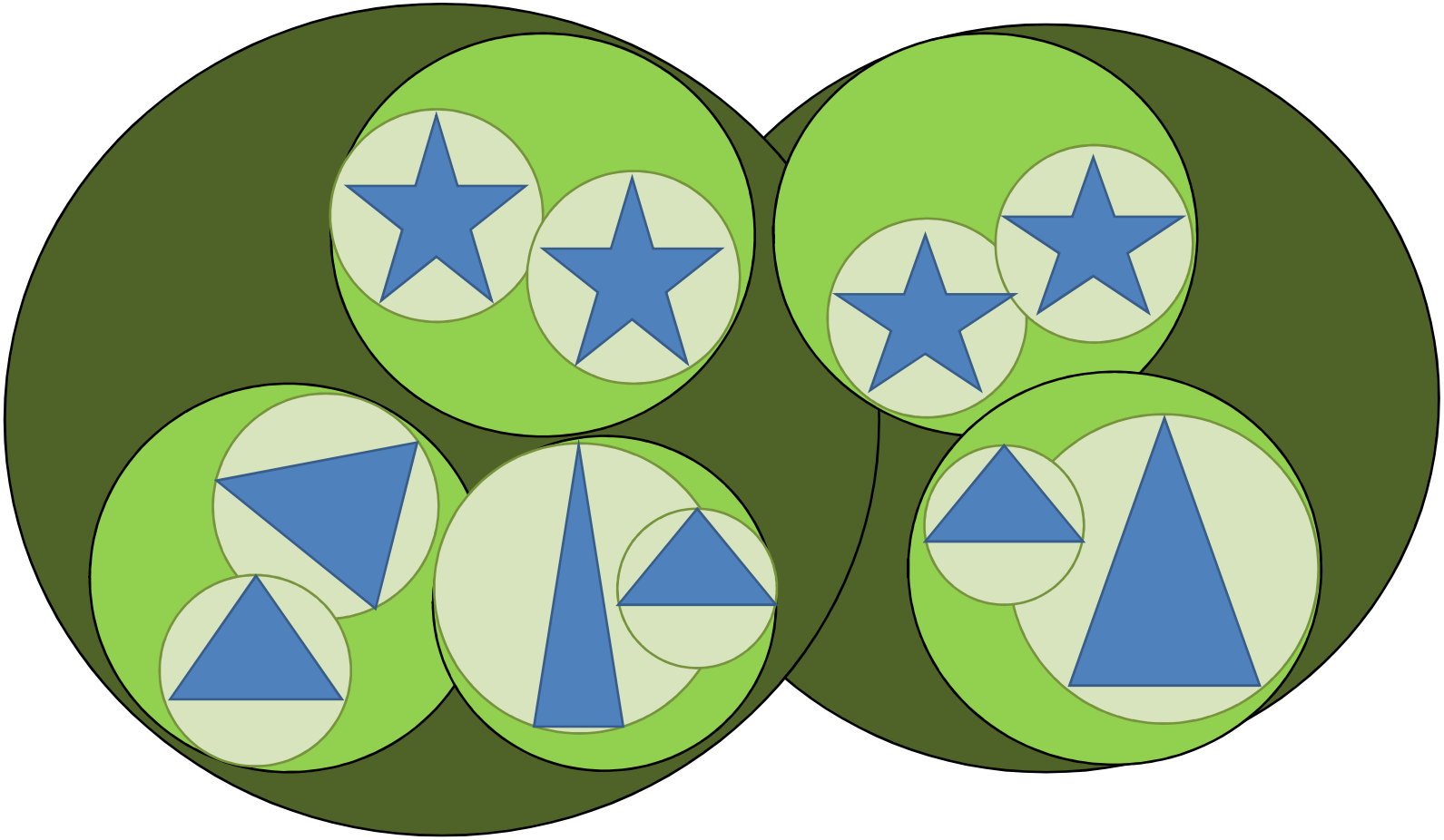
Acceleration

Handling High Numbers of Objects

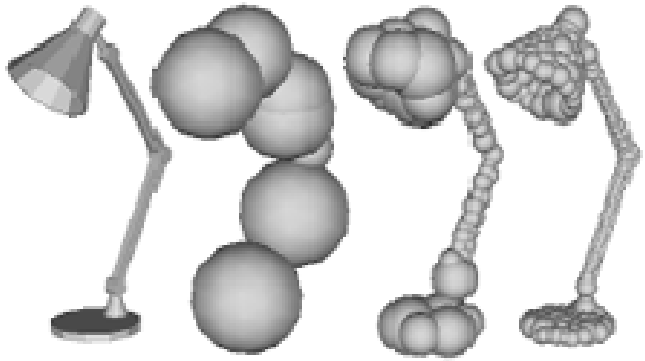
- Have to check each object with every other
  - $N \cdot (N1) \approx N^2$
- Hierarchical iregular subdivision
- Hierarchical Regular suvdivision
- Regular subdivion

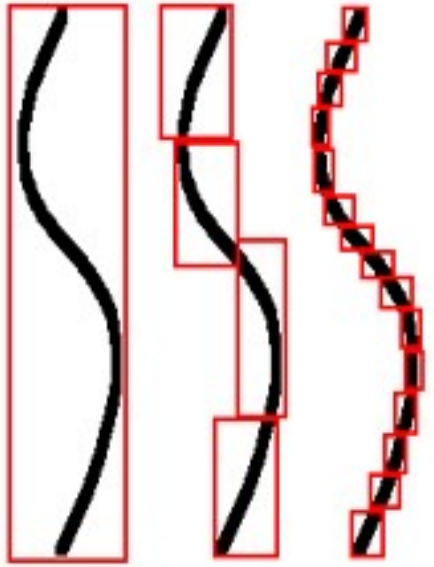
Hierarchy Trees

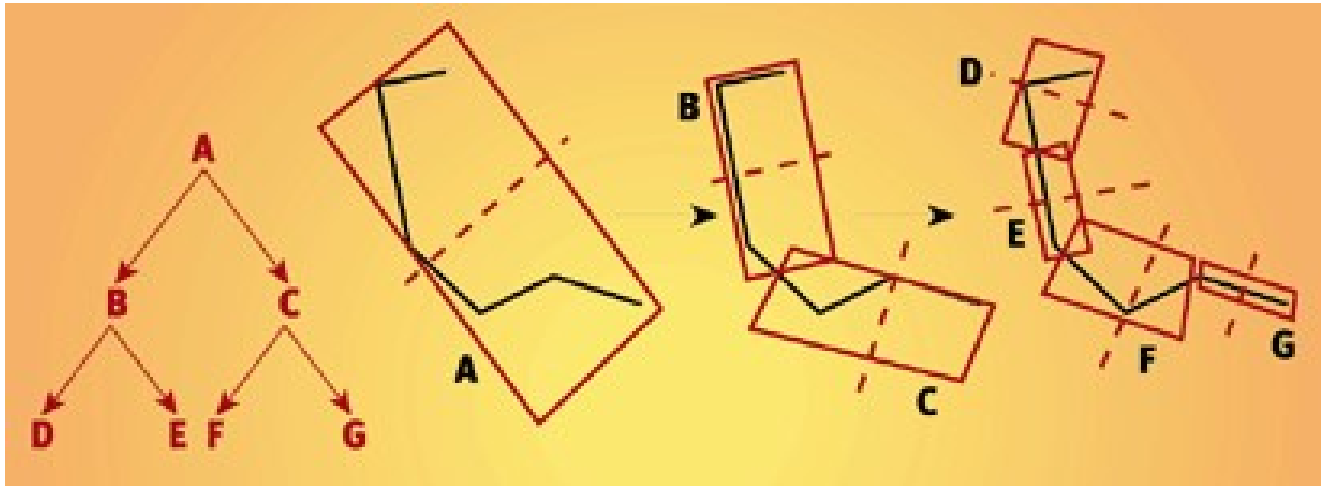
- Bounding Volume Hierarchy = BVH



Hierarchy Trees

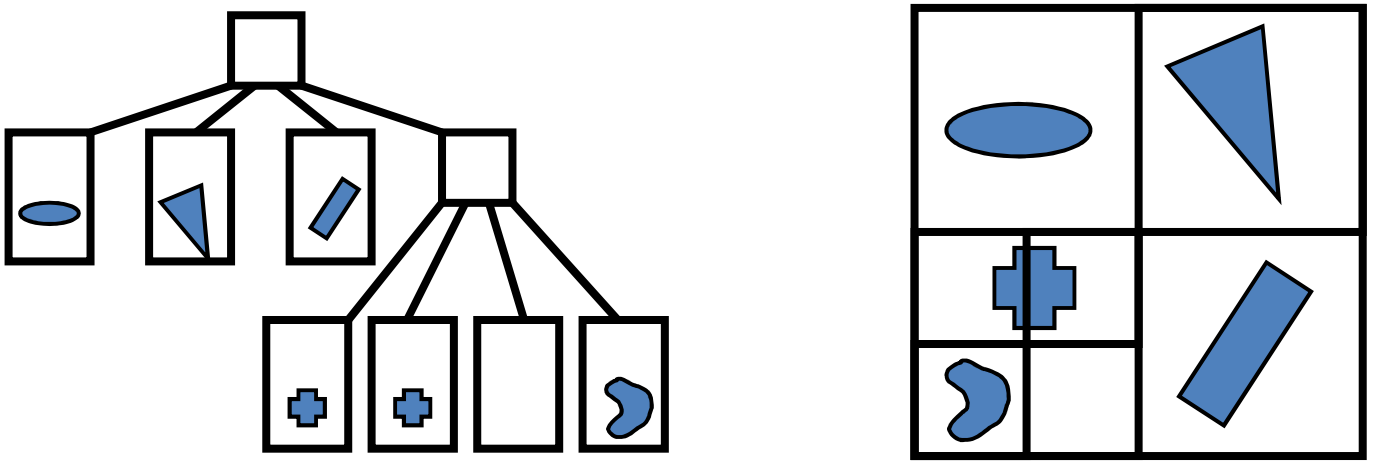




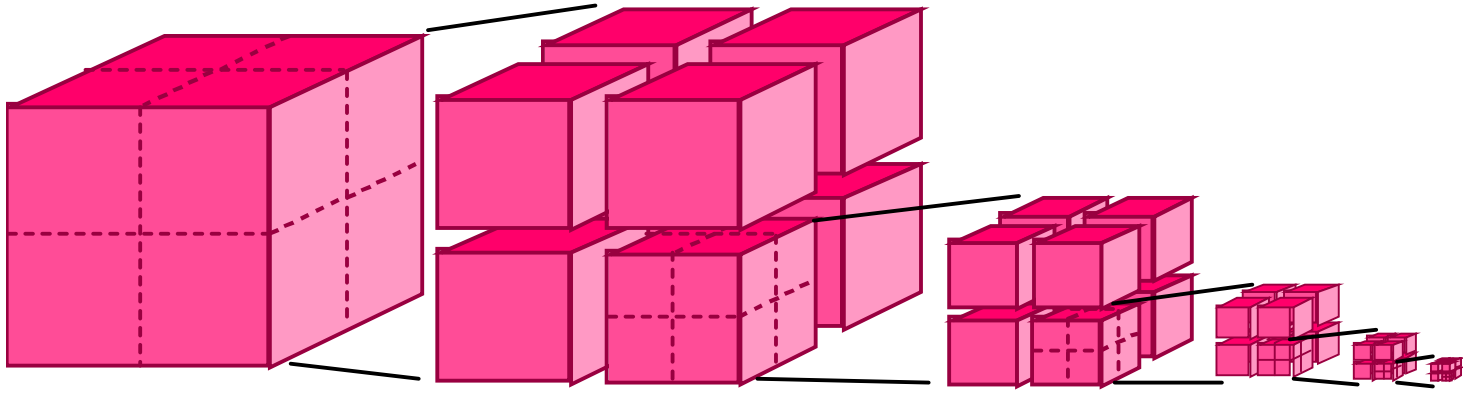


Quad/Octrees

- Quadtree (2D)

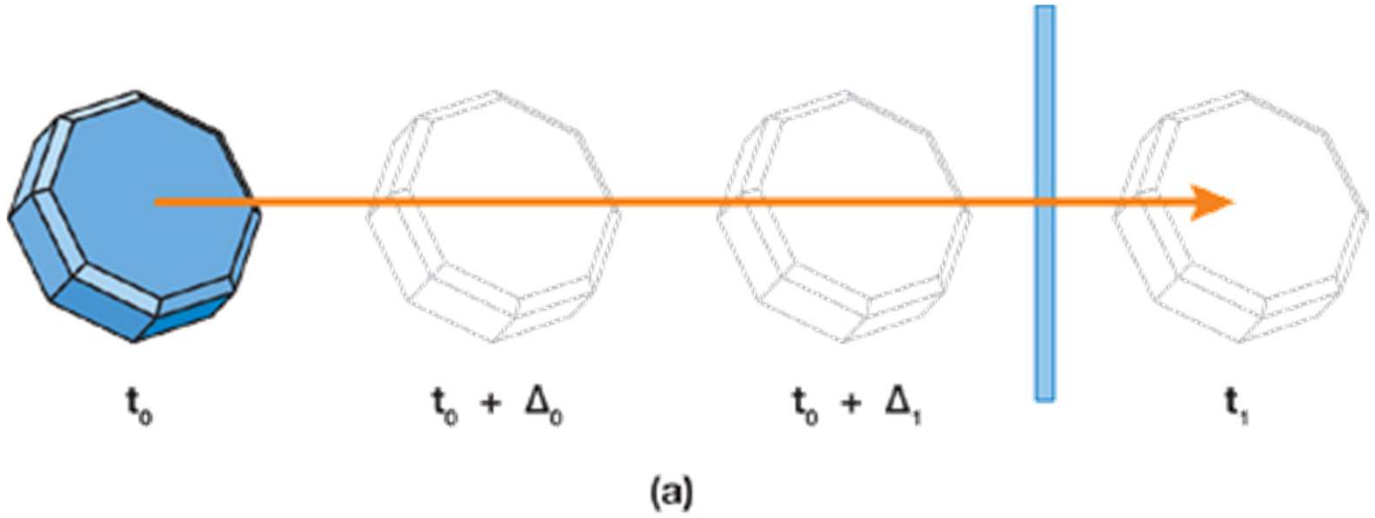


- Octree (3D)



Animated Objects

Trouble with Animated Objects

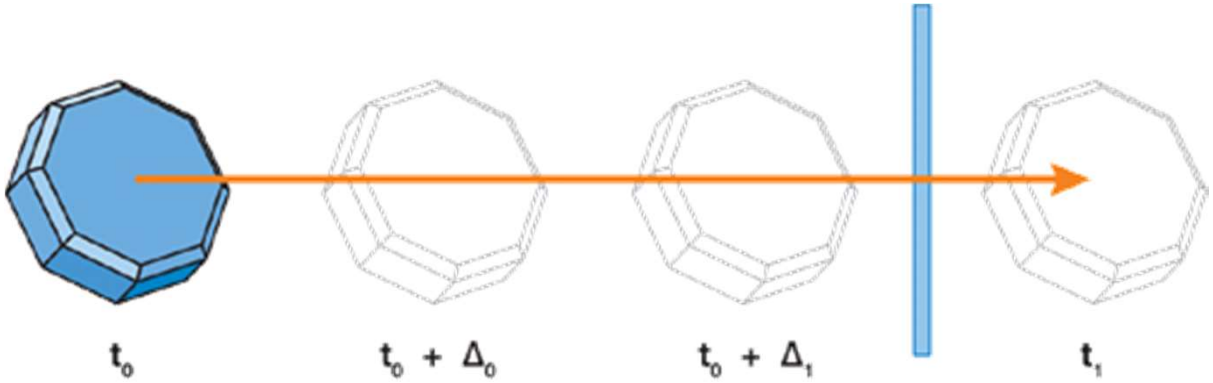


(a)

(b)

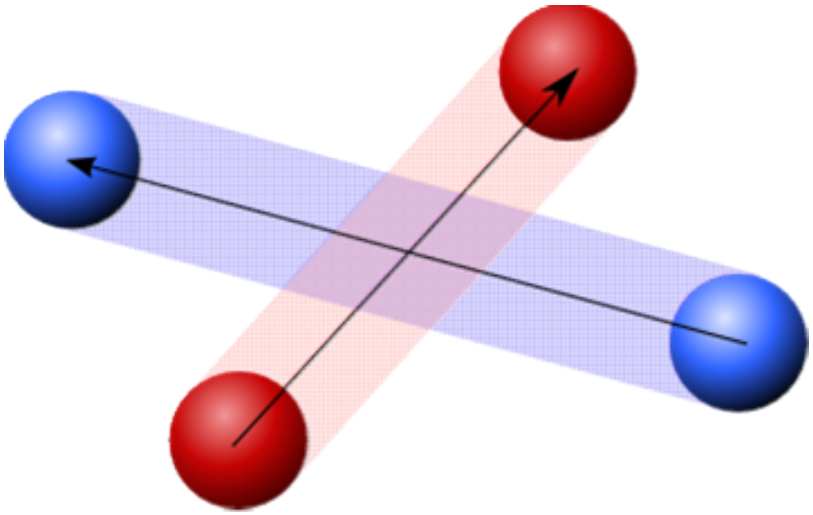
A posteriori (Discrete)

- Advance physics by time step then check for collision
- Simple
  - List of objects → return list of intersections
  - No time variable in calculations
  - Miss actual time of collision
- Need to "fix"



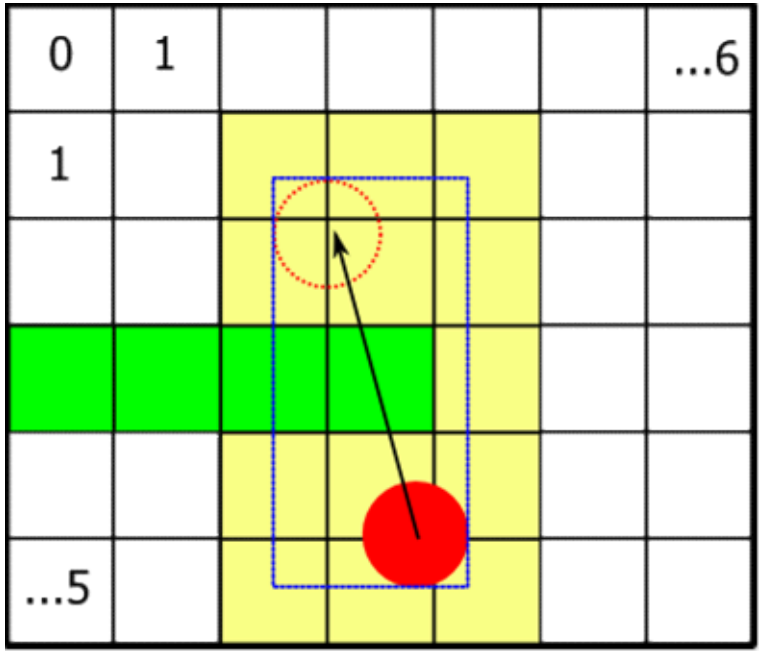
A priori (Continuous)

- A priori (continuous)
  - Predict future movement
    - Trajectories
  - Can be more precise
  - Can be more stable
  - More complex
    - Dimension of time
    - Often no closed form solution (numerical approach)
    - Aware of how objects move
      - Elastic objects (deforming)



Animated Objects - Practical Solutions

- Use extruded geometry
- Use overesized geometry
- …
- Cast ray(s)
- Evaluate often enough
  - Restrict speed
- Extensive testing
- Some cases will be missed



Independent Render and Game Loop

- Do update in predefined intervals
- Independent from rendering loop
  - Slow rendering does not impact update cycle

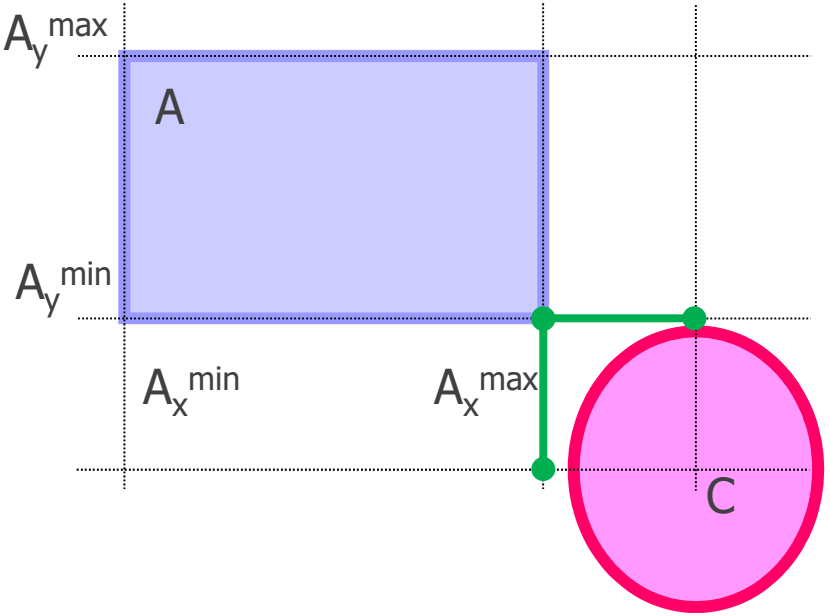
Narrow Phase

Narrow Phase

- Many specialized algorithms
  www.realtimerendering.com/intersections.html
- Often not needed
- Will talk about common cases

Sphere-Box Intersection

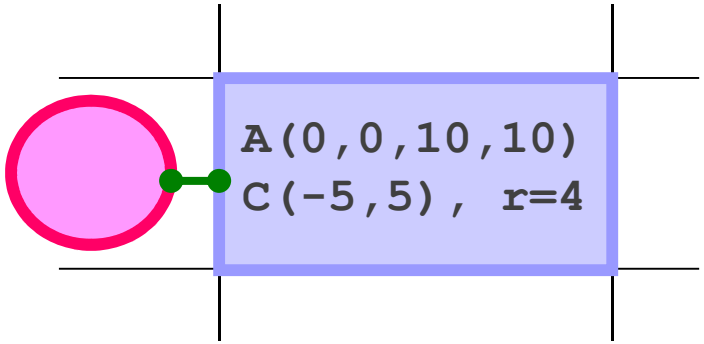
- Idea: Coordinate-wise Euclidean distance



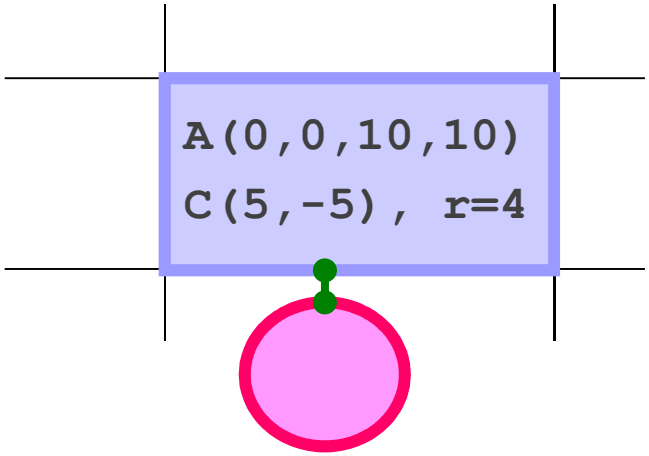

```
d = 0
for each i ∈ {x, y, z}
{
  if (C_i < A_i^min)
    d = d + (C_i – A_i^min)^2
  else if (C_i > A_i^max)
    d = d + (C_i – A_i^max)^2
}
if (d > r^2)
  return DISJOINT
else
  return OVERLAP
```

Sphere-Box Intersection

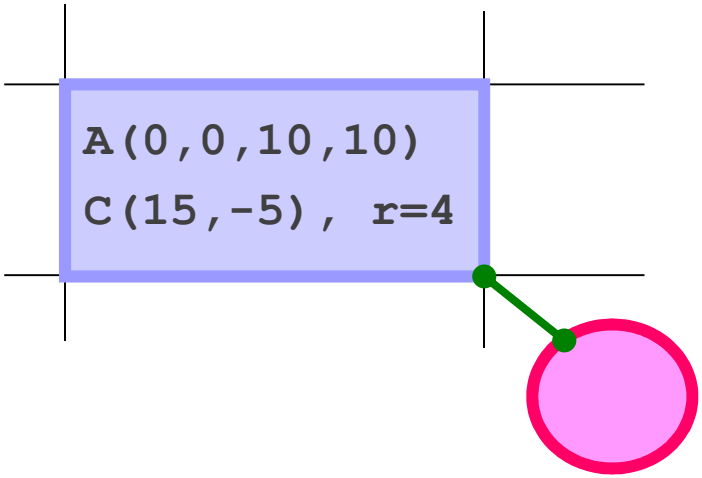
(1)



(2)



(3)



(4)

3D?