Physical Based Animation
Collision Detection - Broad Phase

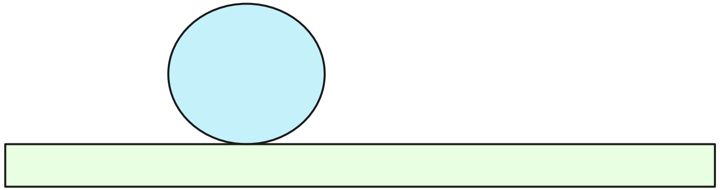
May 5. 2022 - Rasmus Netterstrøm

Contents

Summary

What does a simulation consist of

- **Simulate the motion of the object**
- Detection collision/intersection
- Resolve collision, remove penetration



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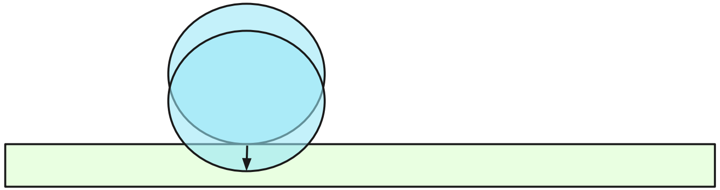

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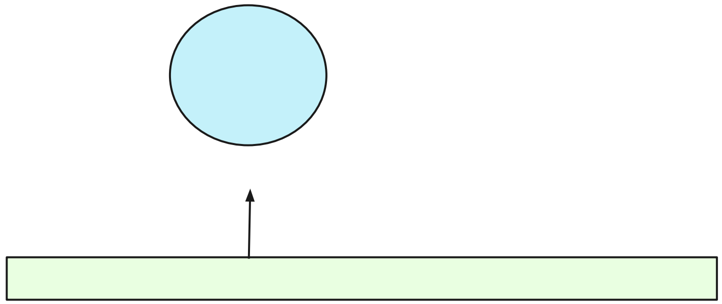


Summary - last time the Narrow Phase

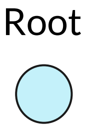
- The main idea of the Narrow Phase is to perform precise collision detection on selected pair of objects.
- The collision detection in the narrow phase is usually more computationally expensive than the simpler collision detection performed in the broad phase.

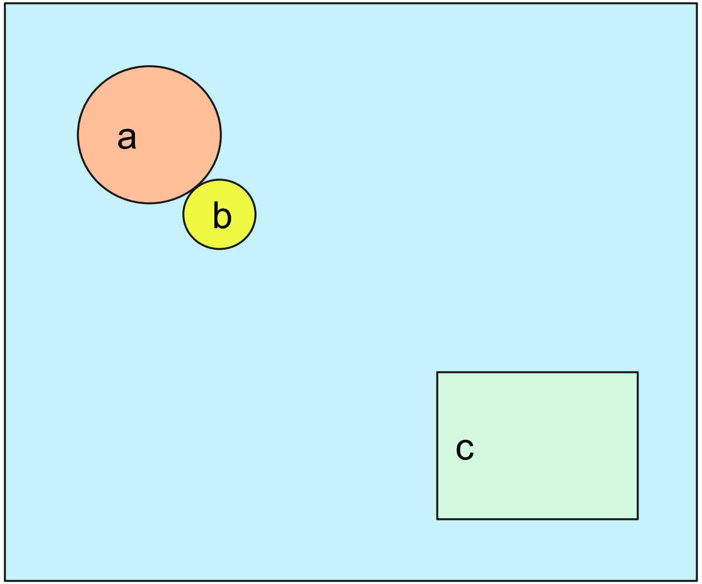
Broad Phase

- A brute force algorithm needs to compare every object with every object. Thus having a running time O(N^2) for N objects.
    - A problem is the collision detection algorithm are computational expensive
- One way to resolve this is with Binary Search Trees (BST) and Sort and Sweep

BST

- Divide the scene into sub-scenes





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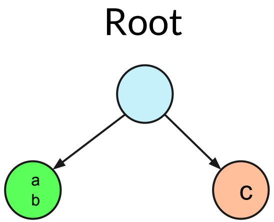

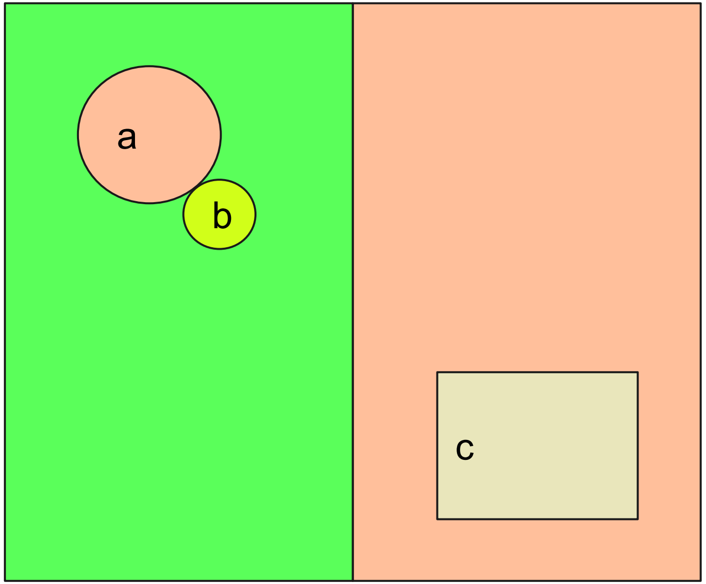

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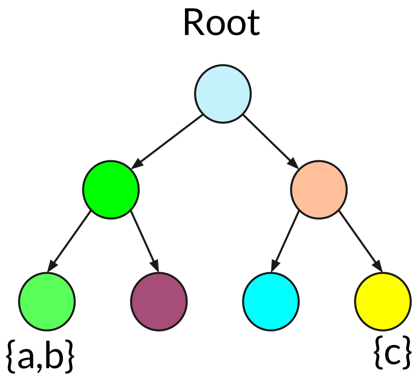

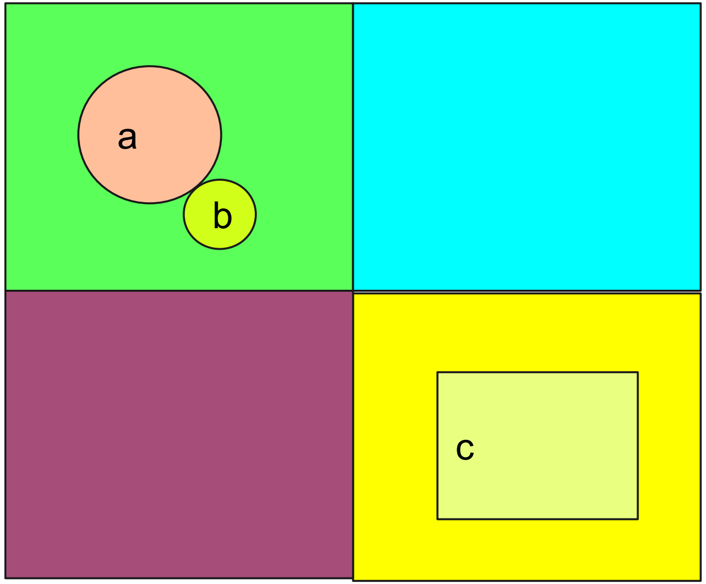

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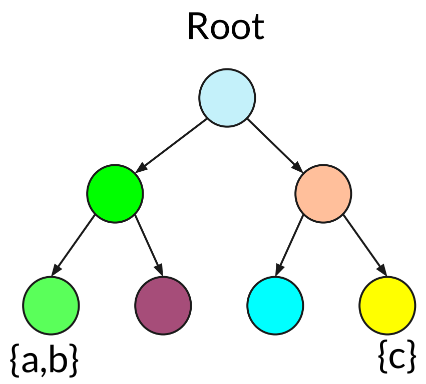

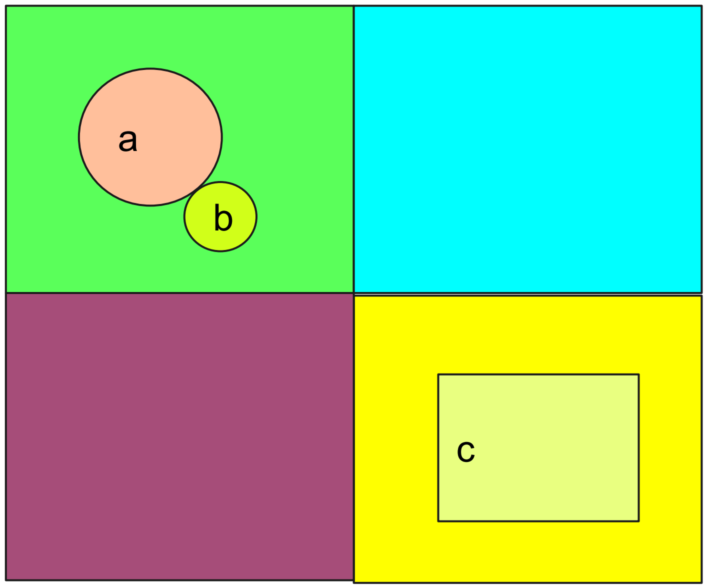

- Objects can be in multiple section.
- The Octree and Quadtree are commonly used examples of BSP trees.
- Only divide if the number of objects reach a threshold.

Sort And Sweep

- The bounding volume of each object is projected onto a single axis.
- Construct a list of all bounding markers (i.e. two per object, leading to a list of 2n items along a particular axis
- Whenever the start of a bounding volume is found, that object is added to the active list, when the corresponding end of the bounding value is found it is removed from the list.
- Assumption: If two object collide they must intersect on every axis.

Sort And Sweep

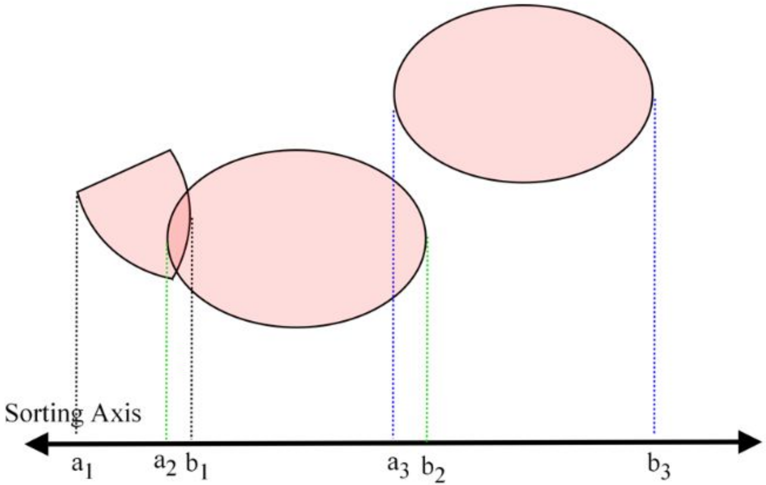

Figure 2. Sort and Sweep - Sorting along each of the primary axes.

Collision Data

- The information which the collision detection algorithms must provide, in order to resolve this intersection
  - The **contact point P** where the intersection has been detected
  - The **contact normal N** which represents the direction vector along which the intersecting object needs to move to resolve the collision
  - The **penetration depth**, i.e. the minimum distance along the normal that the intersecting object must move

Simple Collision Detection Algorithms

- Sphere-Sphere Collision
- Axis-Aligned Bounding Box
- Sphere-Plane Collision

Sphere-Sphere Collision

If the distance between the centres of the two spheres is less than the sum of the radii of the two spheres, then an intersection has occurred

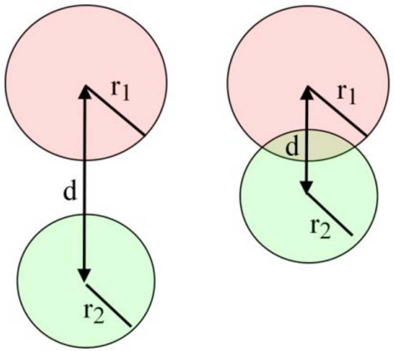

Figure 4. Sphere Sphere Collision - Detecting and gathering contact information for a sphere-sphere collision

Sphere-Sphere Collision

Consider r1 and r2 are the sphere radius’ and c1 and c2 are the sphere positions,
Then an intersection has occurred if:

$$
\begin{aligned}
d &< r_1 + r_2 \\
d &= |c_0 - c_1| \\
&= \sqrt{(x2 - x1)^2 + (y_2 - y_1)^2 + (z_2 - z_1)^2}
\end{aligned}
$$

You may avoid the sqrt root for efficiency

Sphere-Sphere Collision

The collision response is then computed by
S1 and S2 are the sphere centres

$$p = r_1 + r_2 - d$$
$$N = |S_1 - S_2|$$
$$P = S_1 = N(r_1 - p)$$

Axis-Aligned Bounding Box

- Each simulated object is represented as a bounding box aligned with the axes of the world
- There is an overlap of all three axes then an intersection has occurred
- An overlap along a particular axis has happened if the distance between the centres of the two boxes on that axis is less than half the sum of the boxes' lengths along that axis

$$|x_2 - x_1| < 0.5(w_1 + w_2)$$
$$|y_2 - y_1| < 0.5(h_1 + h_2)$$
$$|z_2 - z_1| < 0.5(l_1 + l_2)$$

Axis-Aligned Bounding Box

- The bounding boxes need to be axis-aligned, so they can not rotate as the object they represent moves around the world
- No collision response generated

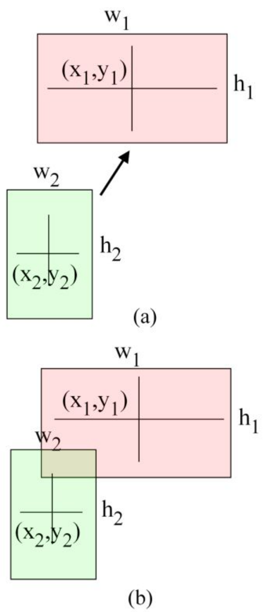

Figure 5. **Axis Aligned Bounding Box (AABB)** - Detecting and gathering contact information for a AABB collision

Sphere-Plane Collision

- Idea: plane equation can be used to calculate how far a point is from an infinite plane
- If this distance is less than the radius of a sphere, then the sphere intersects the plane

$$Ax + By + Cz + D = 0 \qquad (7)$$

where (A,B,C) is the normal to the plane, D is the distance of the plane from the origin, and (x, y, z) is the position of the test point.

Sphere-Plane Collision

- More specific, a sphere at position S of radius r, intersects a plane with normal N at distance d from the origin if

$$N \cdot S + d < r$$

- The rest of the collision response is then computed by

$$p = r - (N \cdot S + d)$$
$$P = S - N(r - p)$$