Ang Jin Yang

Bounding volume hierarchy (BVH)

Bounding Volume Hierarchy (BVH) is a hierarchical spatial data structure used in computer graphics, collision detection, and ray tracing. It organizes geometric primitives (such as triangles or spheres) into a tree-like structure, where each node represents a bounding volume enclosing its children. The primary reasons for using BVH in this showcase is to reduce the number collision detection, instead of testing each object against every other object, BVH allows quick culling of entire subtrees if their bounding volumes don't intersect, thus reducing the number of detailed intersection tests needed.

Implementation of BVH

Objects strategically positioned in this showcase mimic a dynamic scene. BVH construction can employ either a Top-Down or Bottom-Up approach, both of which will be discussed here. Additionally, BVH can utilize either Axis Aligned Bounding Boxes (AABB) or PCA spheres for construction.

All entities in this scope will have their bounding volumes (AABB, OBB, or PCA sphere) calculated for BVH.

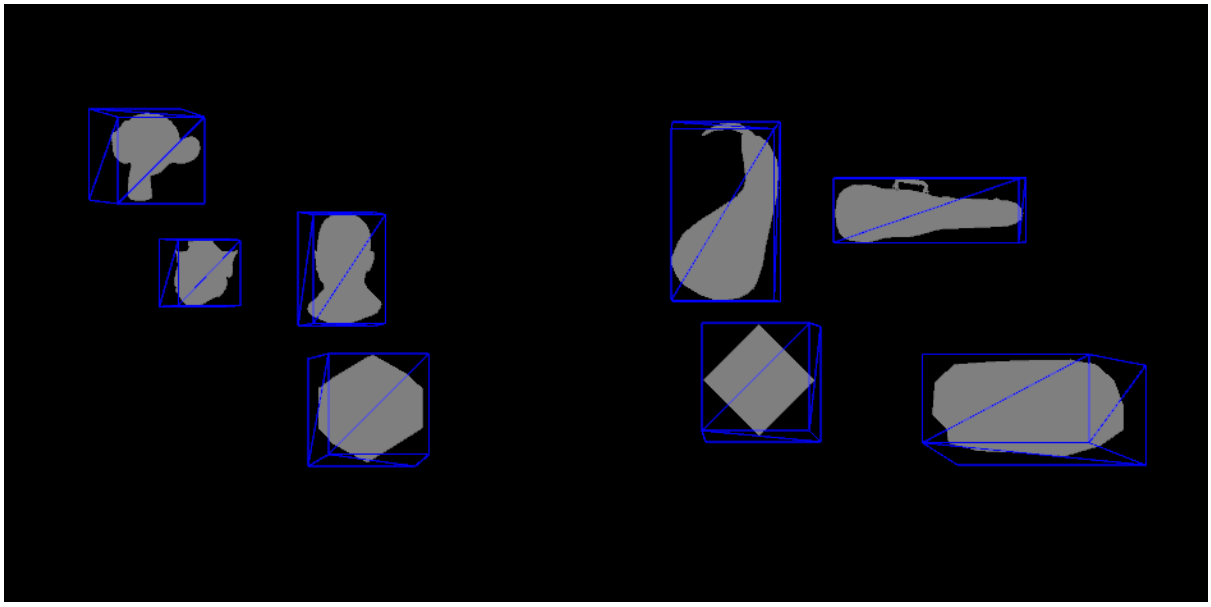

Figure 1: Strategic arrangement of objects with their respective bounding volumes that can be changed between AABB, OBB and PCA sphere.

Levels of BVH

To differentiate between the BVH levels, the levels have been colour coded as such:

Level	Colour
0	Red
1	Orange
2	Yellow
3	Cyan
4	White
5	Purple

Top-Down Approach

The BVH Top-Down approach begins with a single bounding volume enclosing all objects. It's recursively split by calculating centres along an axis, sorting them, and computing total volumes for resulting child nodes. The axis with the minimum volume after splitting is chosen. This continues until a termination condition is reached.

Termination condition

Due to brevity, the termination condition for the hierarchy in this showcase will end when leaf node have a single object, but multiple other conditions have been explored and implemented. There are namely limiting the tree height and allowing a set amount of child in the leaf node.

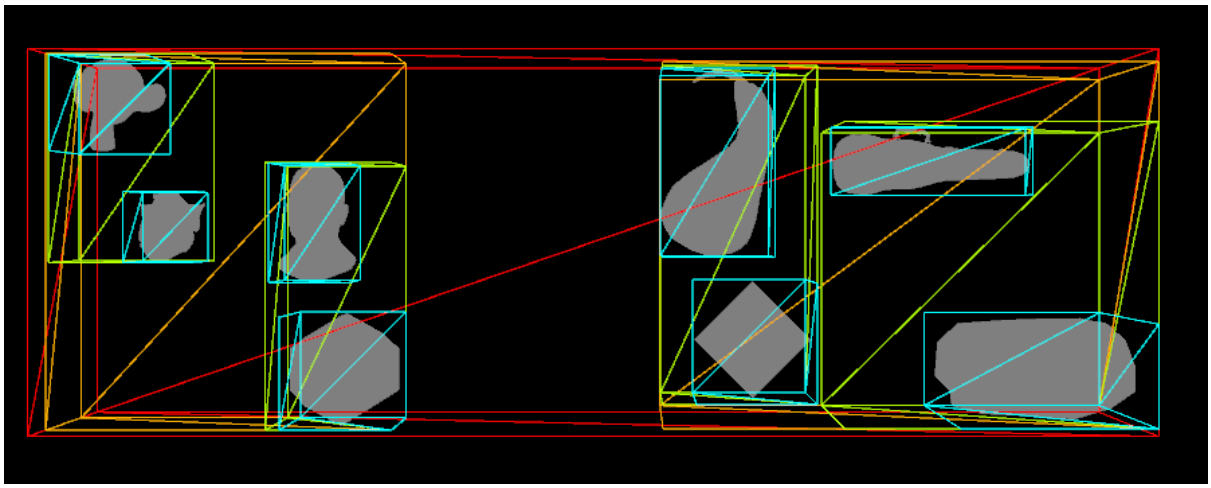

Figure 2: Top-Down BVH constructed with AABB bounding volume.

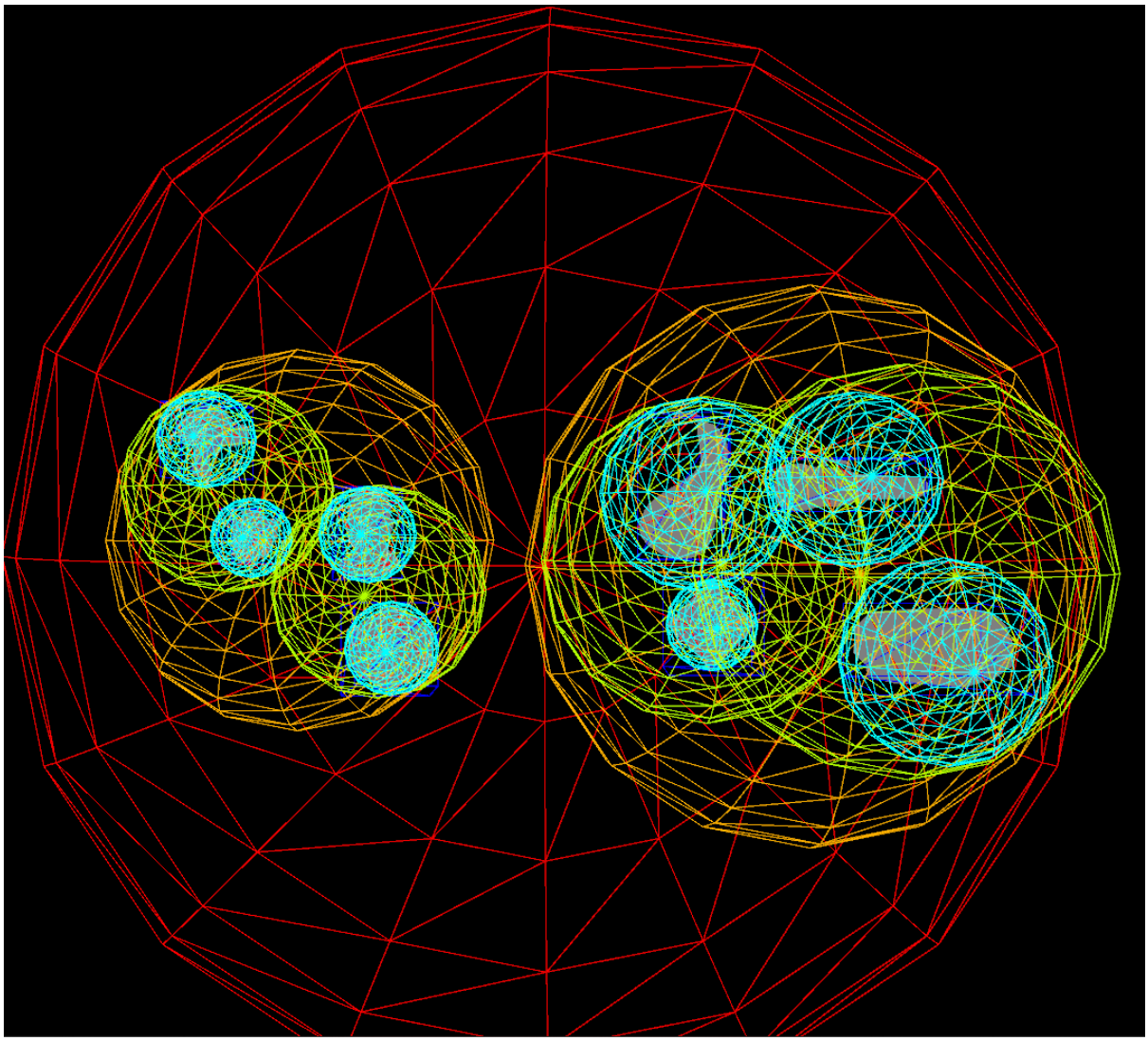

Figure 3: Top-Down BVH constructed with PCA sphere bounding volume.

Bottom-Up Approach

The Bottom-Up approach to constructing a BVH starts with individual bounding volumes for each object in the scene. These initial bounding volumes are then recursively merged to form larger bounding volumes.

Merging Criteria

The project utilizes a combination of three tests for constructing the BVH:

- Nearest Neighbour: Aims for a balanced structure with minimal overlap between bounding volumes.
- Minimum Combined Child Volume: Focuses on minimizing the overall size of the BVH.
- Minimum Combined Child Surface Area: Suitable for future implementations involving surface area intersections.

By incorporating elements from all three tests, the project selects the best combination to achieve an optimized BVH structure.

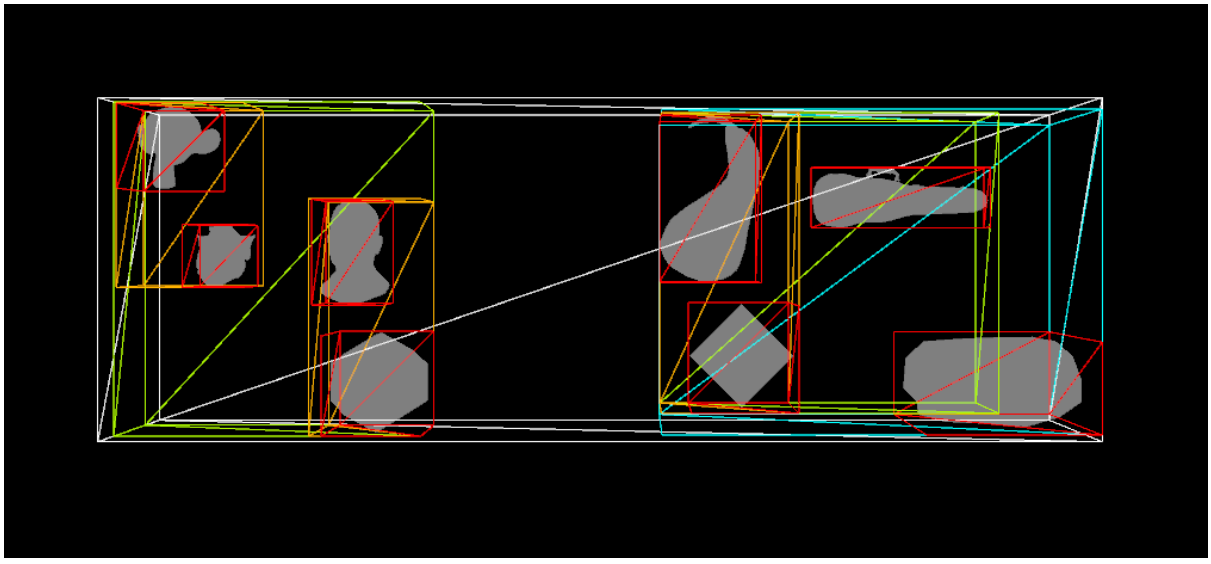

Figure 4: Bottom-Up BVH constructed with AABB bounding volume.

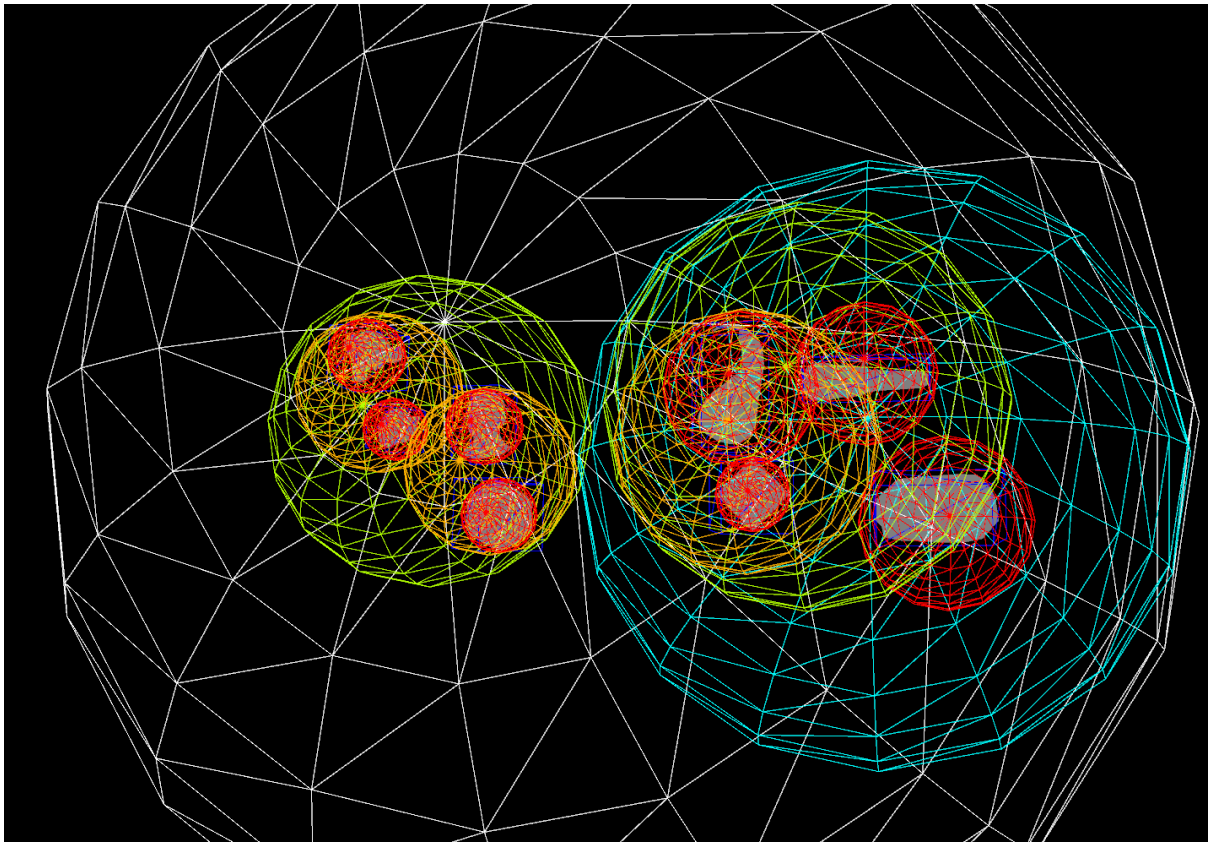

Figure 5: Bottom-Up BVH constructed with PCA sphere bounding volume.

Conclusion

Top-Down BVH construction is great for fixed spatial structures or when starting with a high-level overview, utilizing a predefined bounding volume. Conversely, Bottom-Up is handy for dynamic scenes, beginning with individual bounding volumes for objects and merging them iteratively to adaptively adjust the hierarchy.