Ang Jin Yang

Spatial Partitioning using Adaptive Octree and KD-tree.

Spatial partitioning is a fundamental technique in computer graphics and computational geometry for efficiently organizing and querying spatial data. Two popular methods for spatial partitioning are Adaptive Octrees and KD-trees.

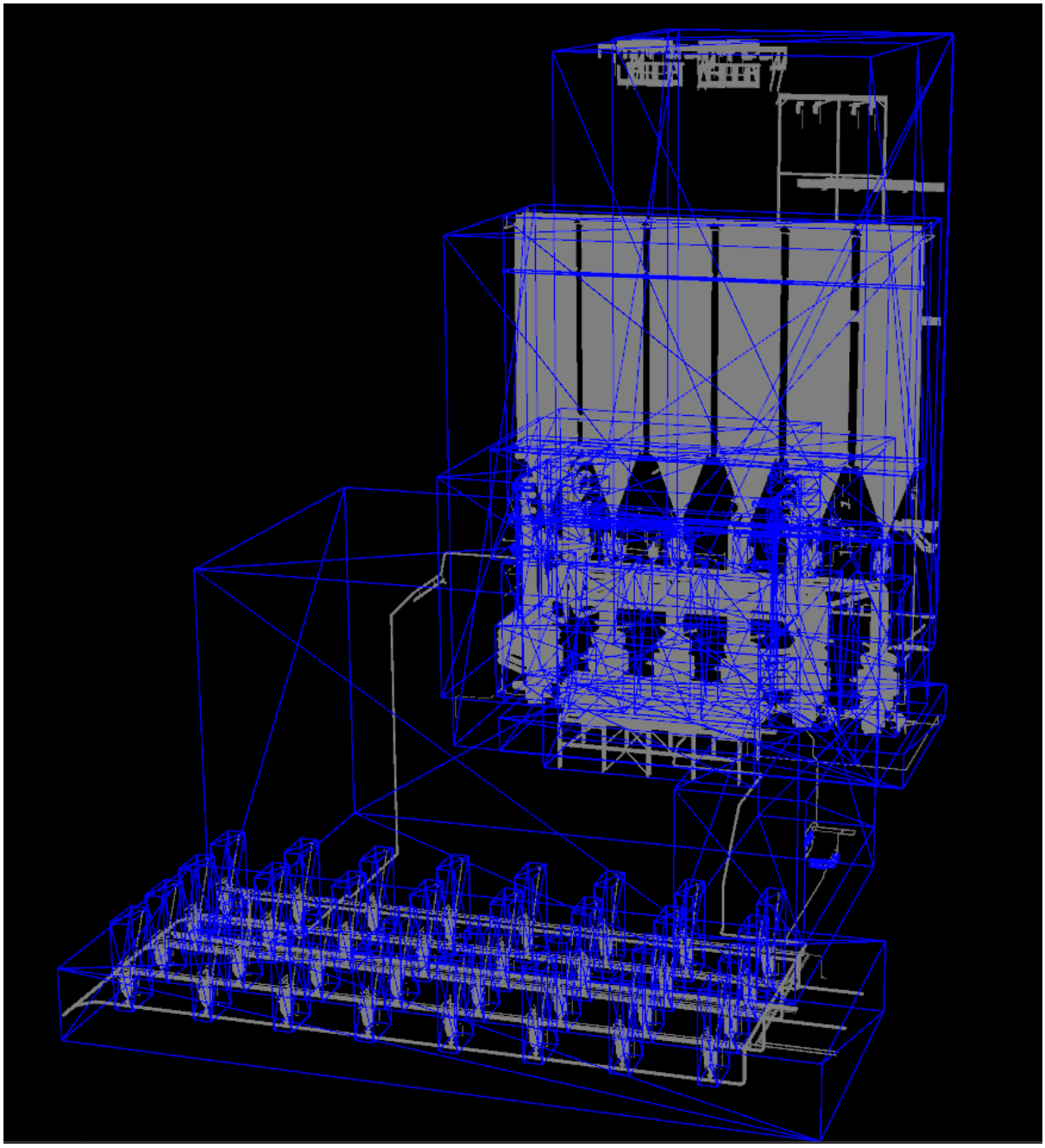

Figure 1: Model used for this discussion that is made up of 81 distinct objects with their respective bounding volume rendered.

Level of tree

To aid visualization of the tree's depth, each level is assigned a random colour. While there may be occasional colour duplications due to randomness, each colour accurately represents its respective level. This strategy ensures that despite numerous possibilities, each level is visually distinct, making it easier to interpret the structure of the tree.

Termination condition

The termination criteria for splitting in the respective trees are based on the number of objects within the current cell. This criterion can be adjusted dynamically by users, allowing them to control the level of detail in the representation of the spatial data.

Adaptive Oct-Tree

An adaptive oct-tree is a data structure commonly used in computer graphics for efficiently representing and organizing three-dimensional (3D) spatial data. It's an extension of the oct-tree, which is a hierarchical tree data structure where each internal node has exactly eight children, corresponding to the eight octants of 3D space.

Implementation of adaptive Oct-Tree

If an object straddles the boundary of two (or more) cells, straddling resolutions designed in this discussion are:

- Associate to a cell with respect to its object centre.
- Associate to the cell representing the current level the object is in

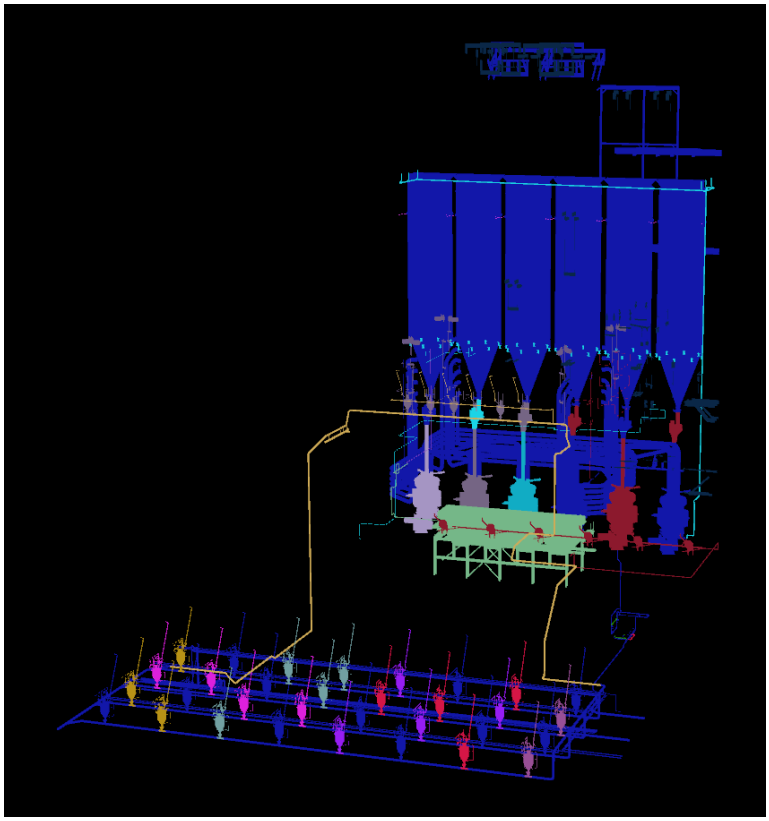

Figure 2: Adaptive oct-tree with terminating criteria set to 10 with straddling resolution of w.r.t its object centre

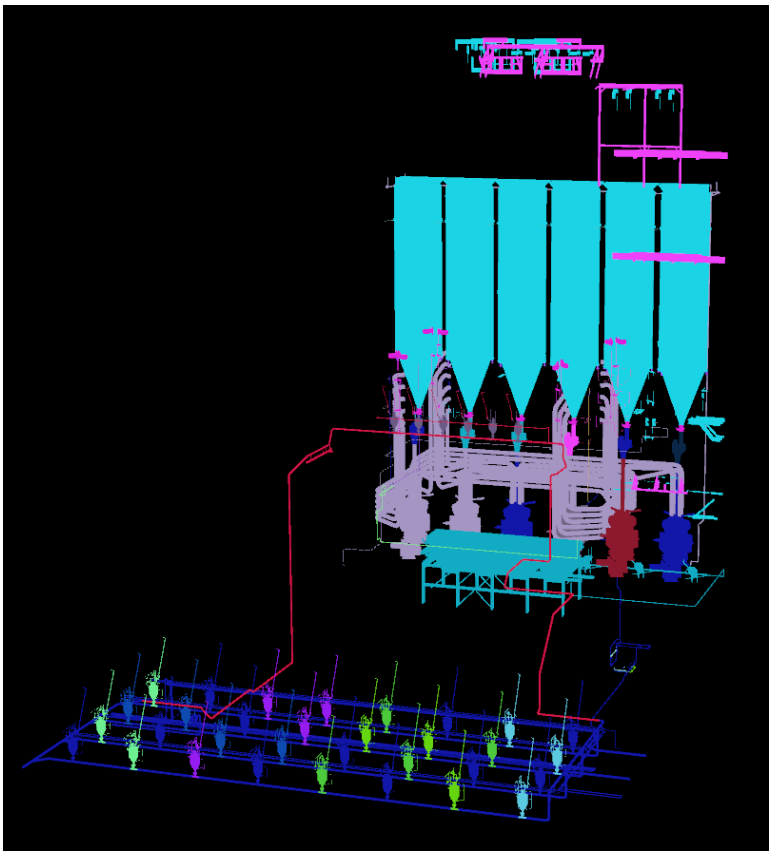

Figure 3: Adaptive oct-tree with terminating criteria set to 10 with straddling resolution of associating to the cell representing the current level the object is in

Comparing straddling resolution

Associating objects to cells based on their centres:

- Advantages: Suitable for varying object sizes and shapes, potentially leading to a more balanced distribution of objects among cells.
- Disadvantages: May require more computational effort and could result in uneven object distribution if objects are not evenly distributed in space.
-

Associating objects to cells based on their hierarchical level:

- Advantages: Provides a straightforward hierarchical organization of objects, useful for certain queries or operations, and ensures objects within the same level are grouped together.
- Disadvantages: Less suitable for varying object sizes or shapes and may lead to uneven distribution of objects among cells if certain levels contain significantly more objects.

KD-Tree

A KD-tree is a data structure for organizing points in a k-dimensional space, commonly used for multidimensional search tasks like finding nearest neighbours or conducting range queries. The "K" represents the number of dimensions in the space being organized.

Implementation of adaptive Oct-Tree

The splitting sequence follows the order of X, Y, and Z axes, with each split involving only one axis. This discussion explores two split-plane choices which are:

- Median of bounding volume centres
- Median of bounding volume extents

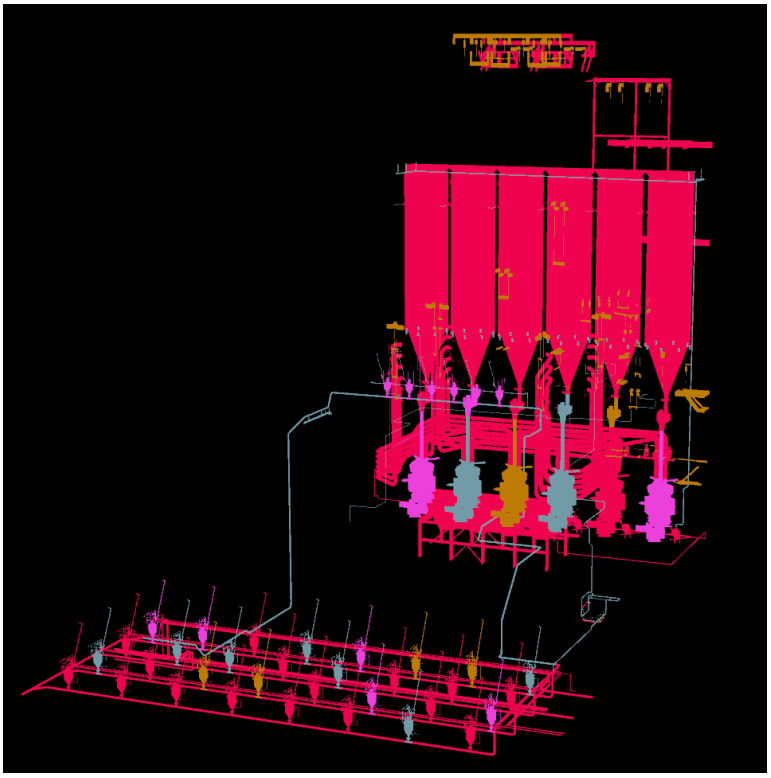

Figure 4: KD-tree with terminating criteria set to 10 with split-plane set to median of bounding volume centre.

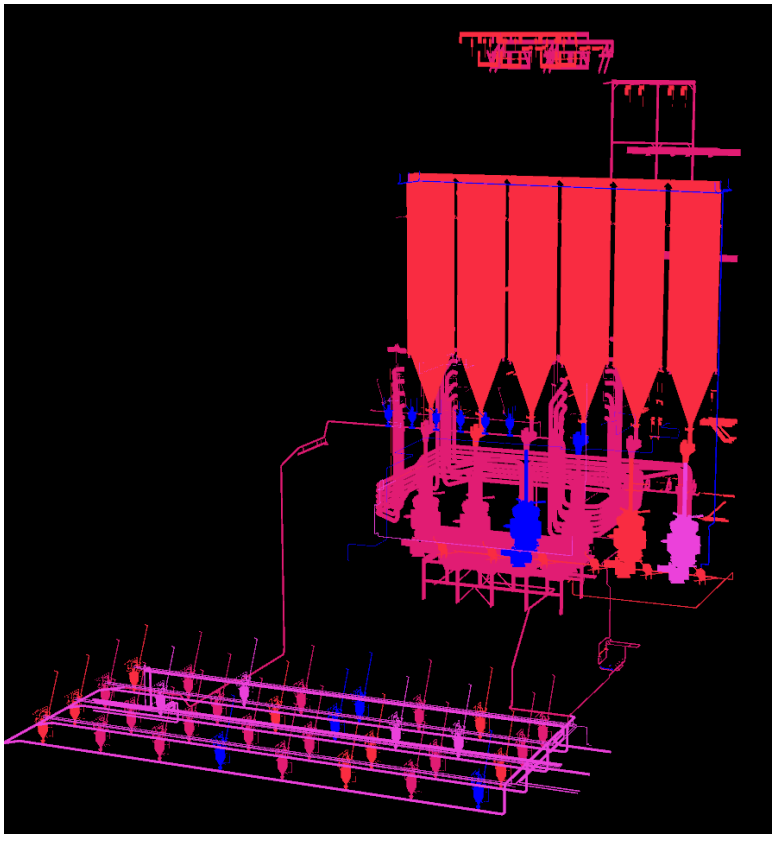

Figure 5: KD-tree with terminating criteria set to 10 with split-plane set to median of bounding volume extents.

Comparing split plane choices

Median of bounding volume centres:

- Advantages: Ensures a balanced distribution of objects among child nodes, leading to a more balanced tree structure.
- Disadvantages: May be influenced by outliers, especially if a few objects have significantly different sizes or shapes, potentially leading to suboptimal splits.

Median of bounding volume extents:

- Advantages: Less susceptible to outliers compared to median of bounding volume centres, as it focuses on the sizes of the bounding volumes rather than their positions.
- Disadvantages: May result in less balanced splits if objects have similar extents but different spatial distributions within the node.

Conclusion

KD-trees are adept at handling high-dimensional data and complex search tasks, whereas octrees excel in partitioning 3D space and accommodating varying object densities.

For dynamic scenes where objects frequently move or change positions, the adaptive nature of octrees makes them the preferred choice. They efficiently handle changes in object densities and distributions, ensuring optimal performance in dynamic environments.