

A Scalable Server for 3D Metaverses

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Metaverses



Metaverses



Metaverses



Metaverses



```
0 default
1 {
2     state_entry()
3     {
4         llSay(0, "Hello, Avatar!");
5     }
6
7     touch_start(integer total_number)
8     {
9         llSay(0, "Touched.");
10    }
11 }
12
```

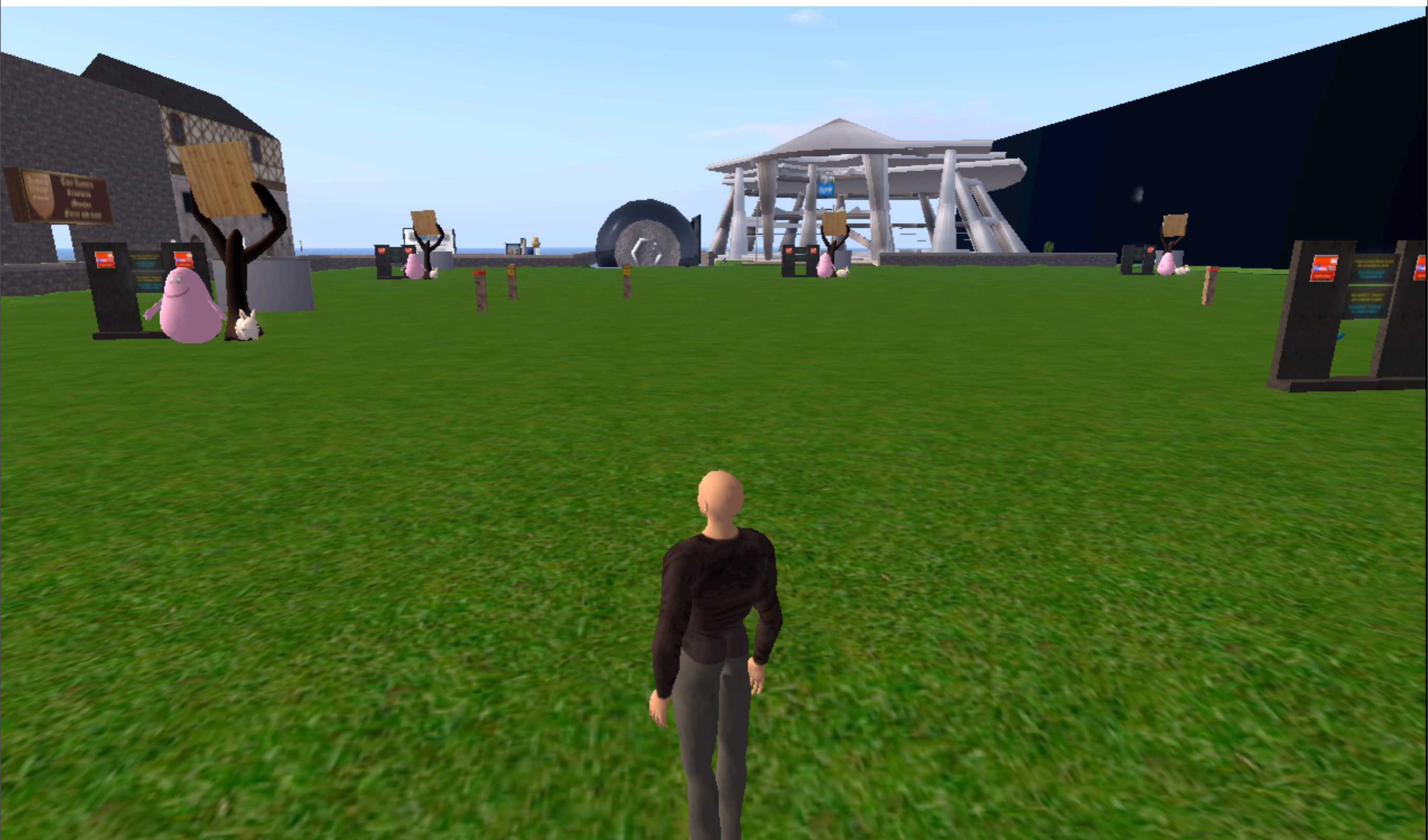

Metaverses

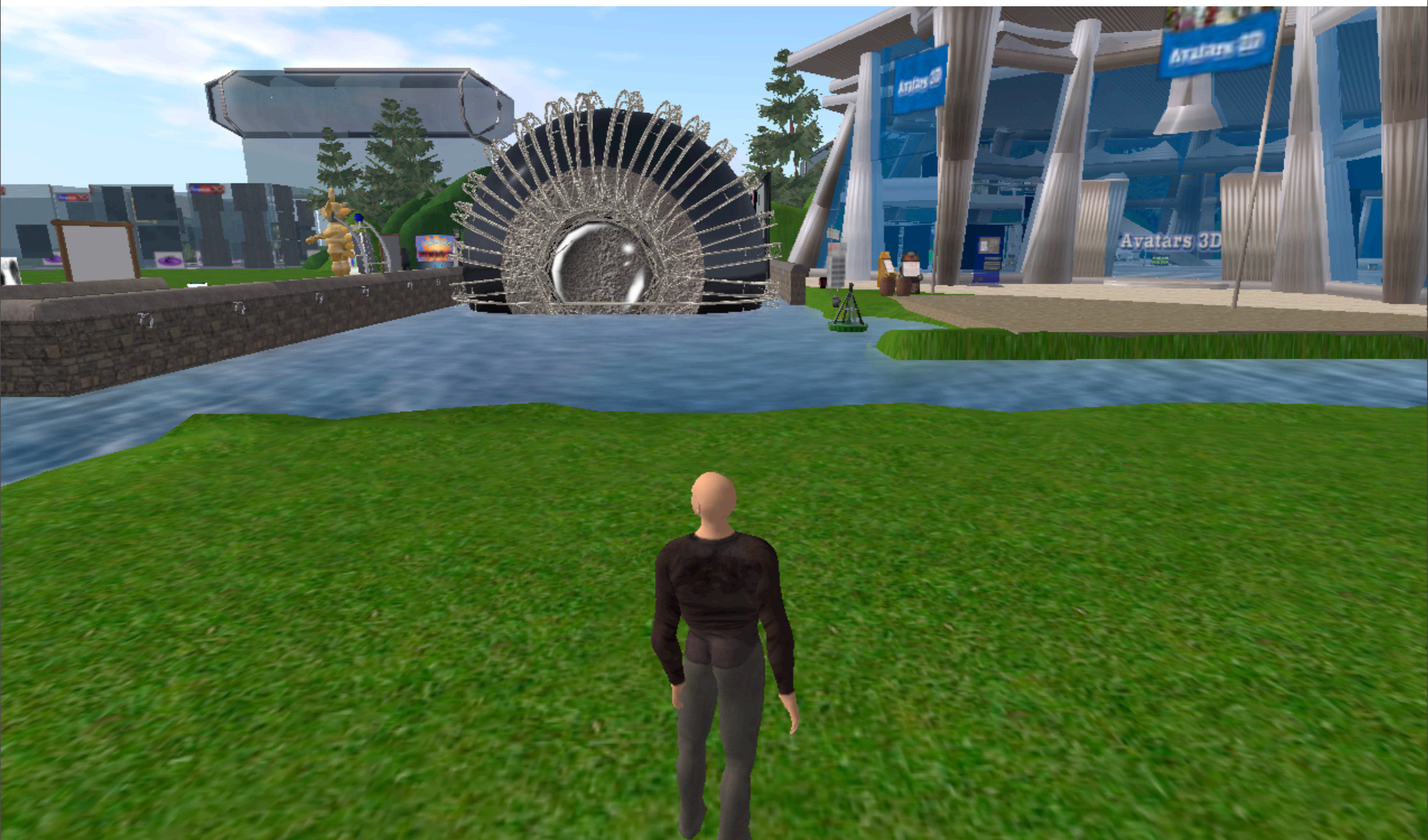
Applications:

- Games
- Augmented reality
- Historical recreations
- Collaborative visualization
- ... what will users create?









These are systems problems.

Object Discovery



Object Discovery

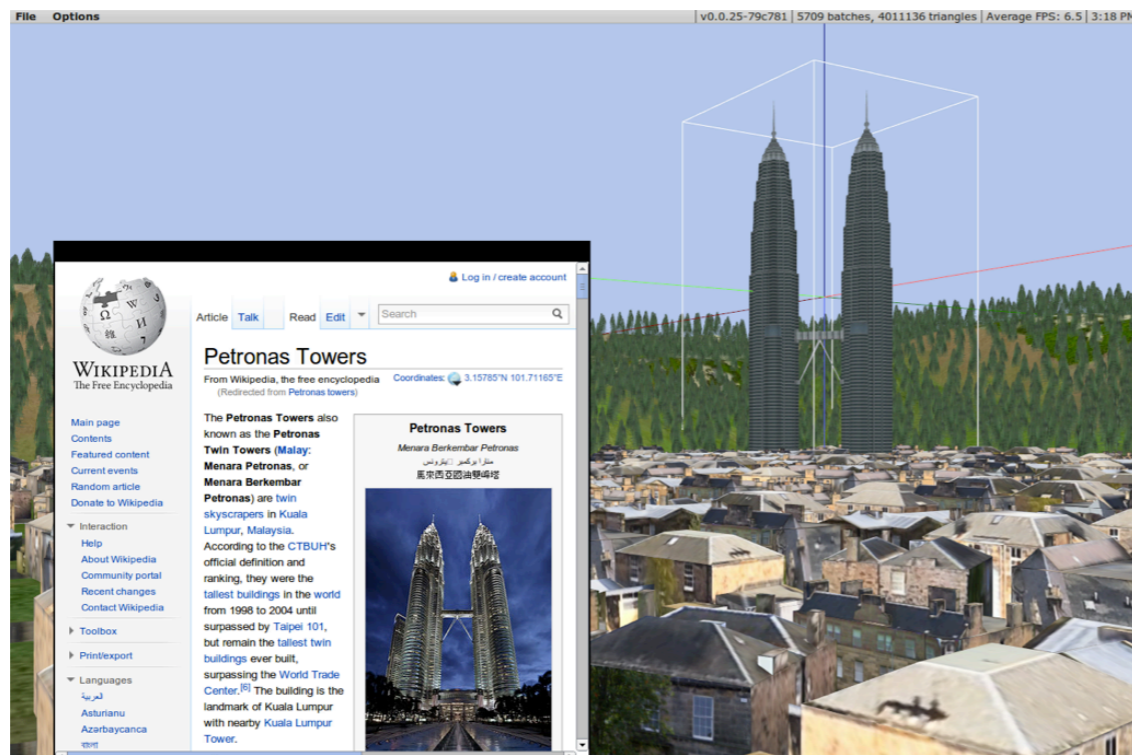


Object Discovery



How do we scale up the world without
limiting the scope of interaction?

Sirikata



Seamless, scalable, and federated metaverses

Insight

The real world scales.

Design Principle

Scale by applying real-world constraints to the system.

Object Discovery

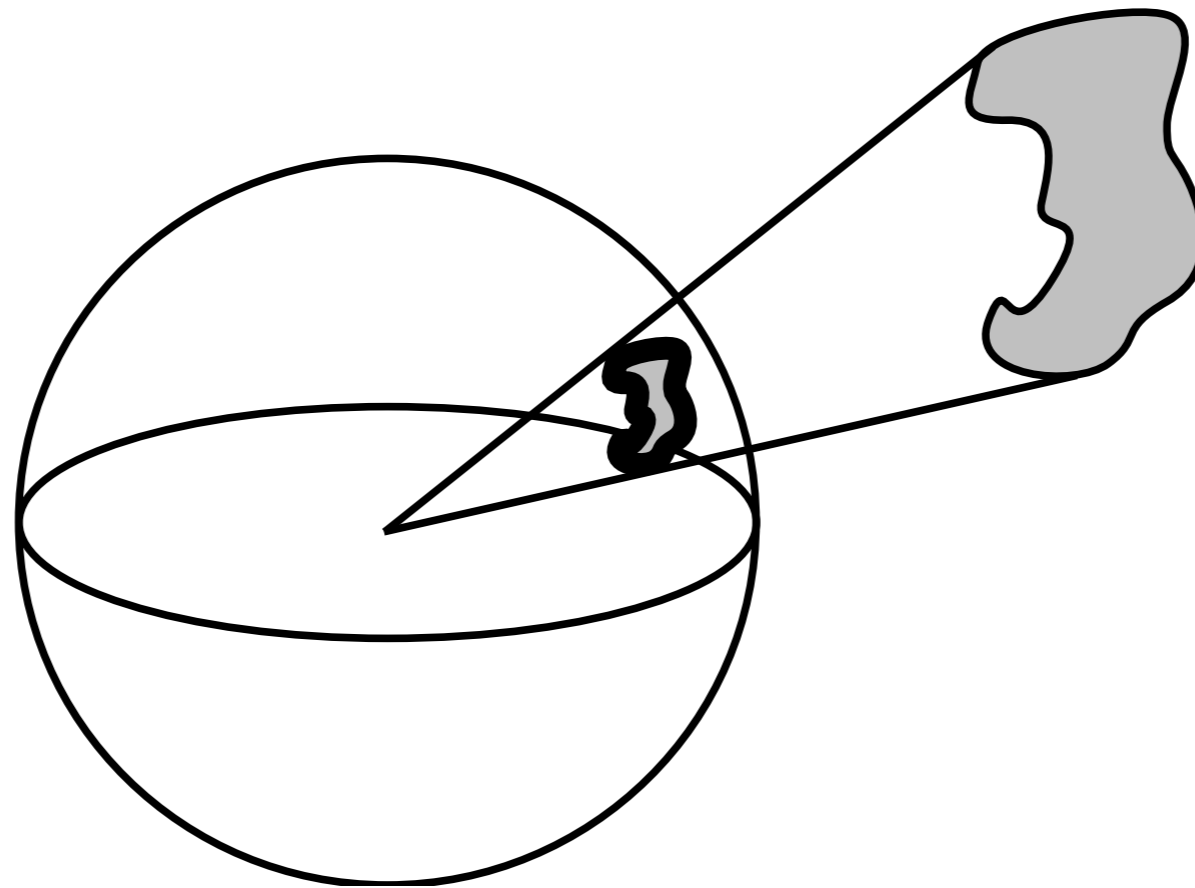


Object Discovery



Solid Angle Queries

Insight: Limited display resolution



Solid angle: how large an object appears

Ideal



Distance, 3000 Objects



Solid Angle, 3000 Objects



Solid Angle & Aggregates, 3000 Objects



Ideal

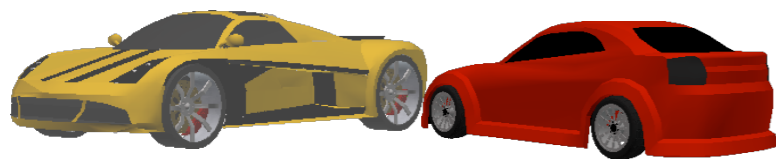
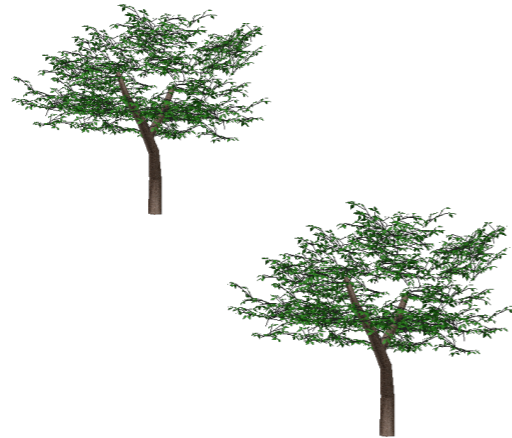


Object Discovery

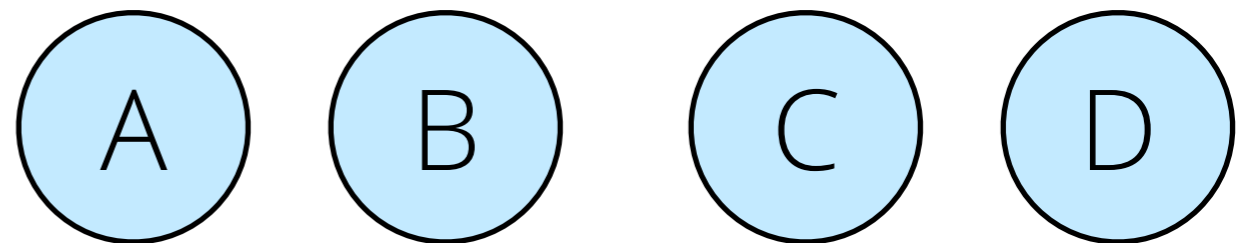
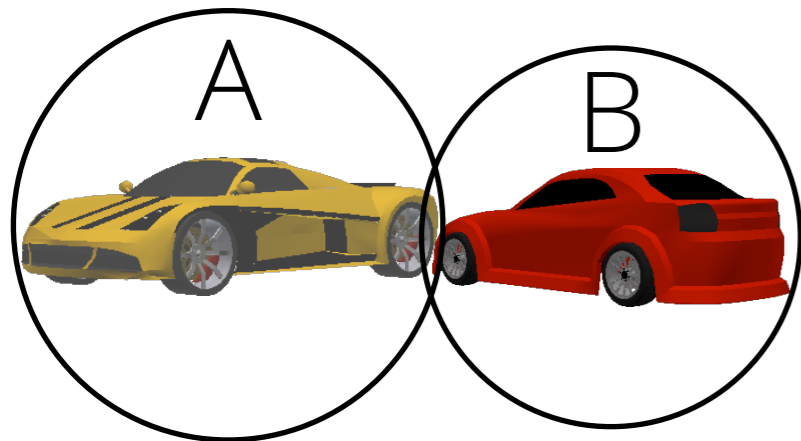
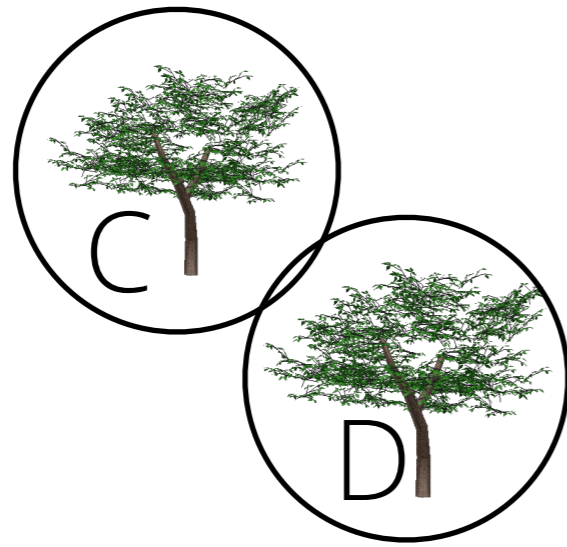
Solid angle queries are global.

How do we efficiently and scalably evaluate solid angle queries?

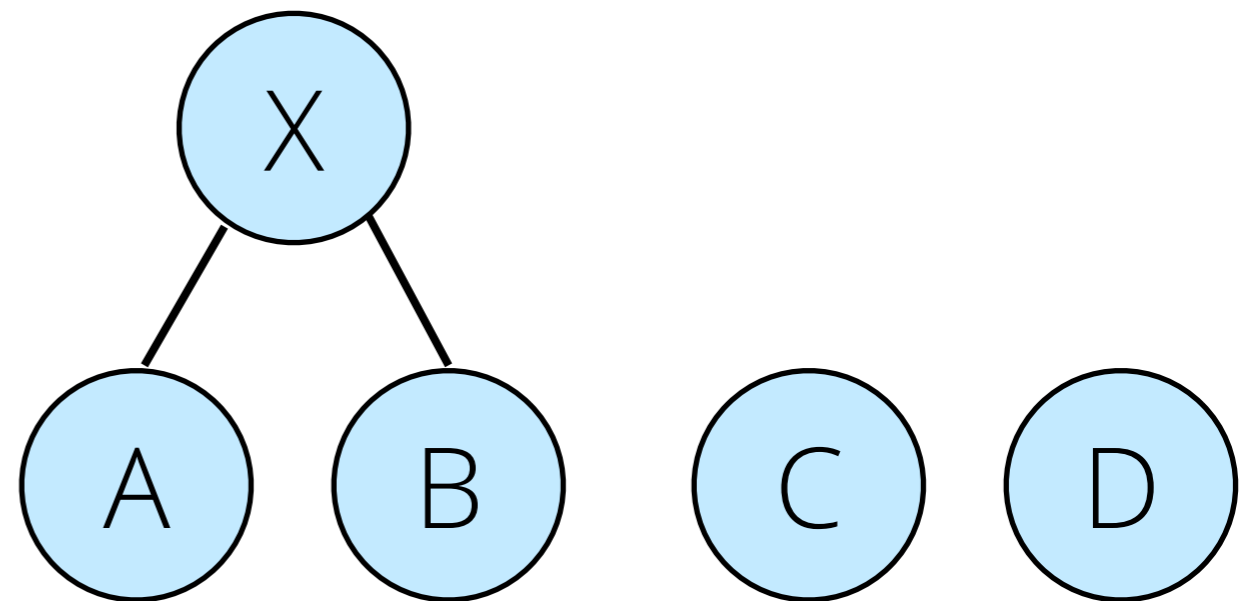
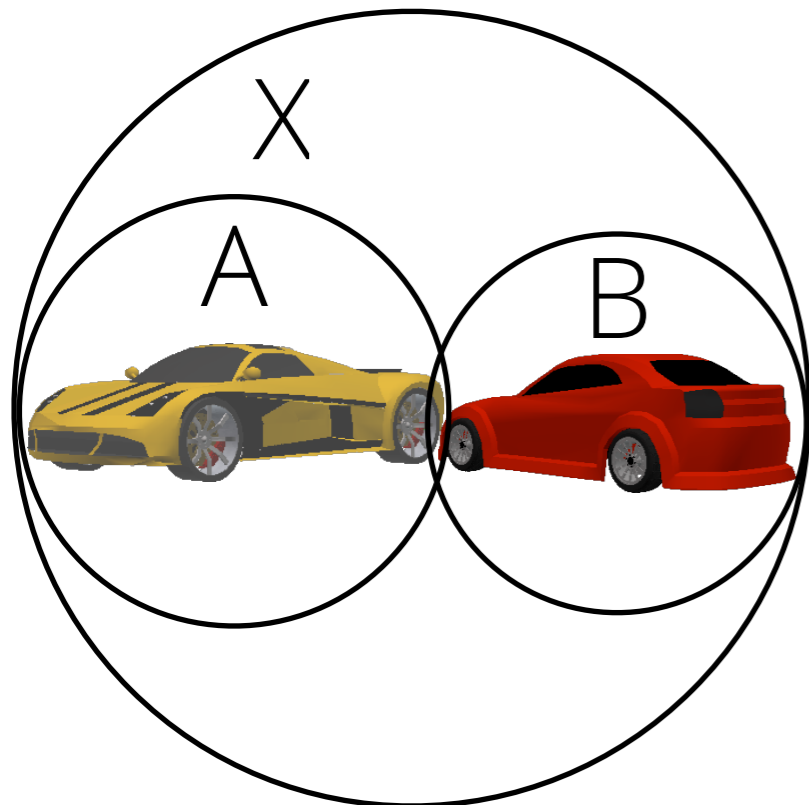
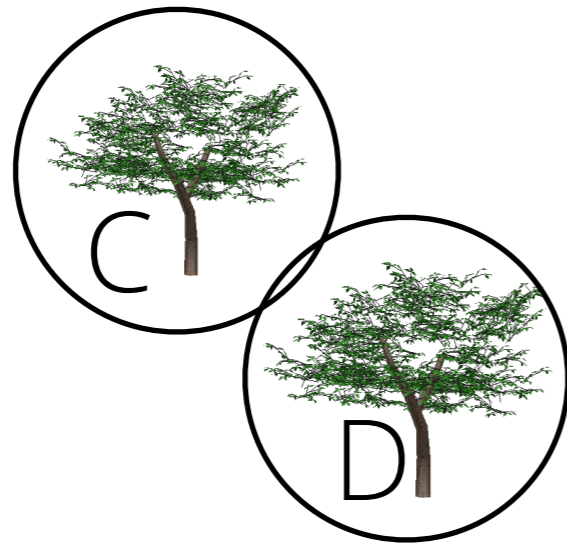
Data Structure - BVH



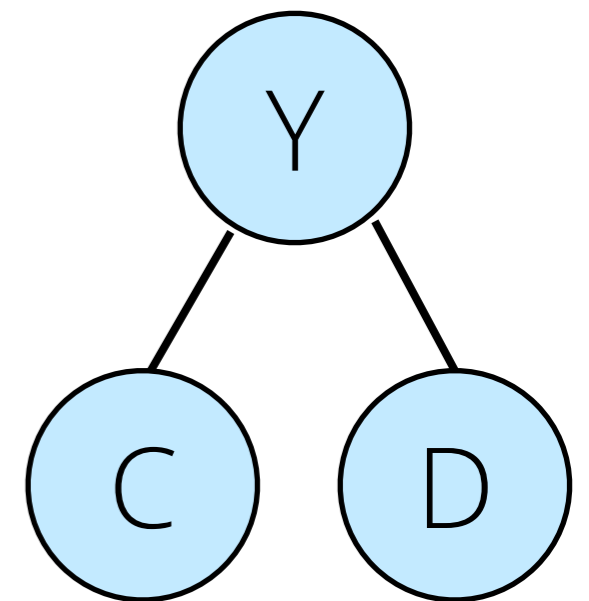
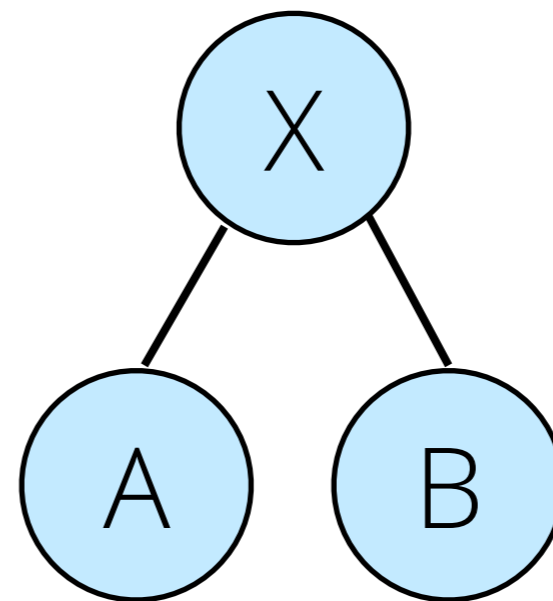
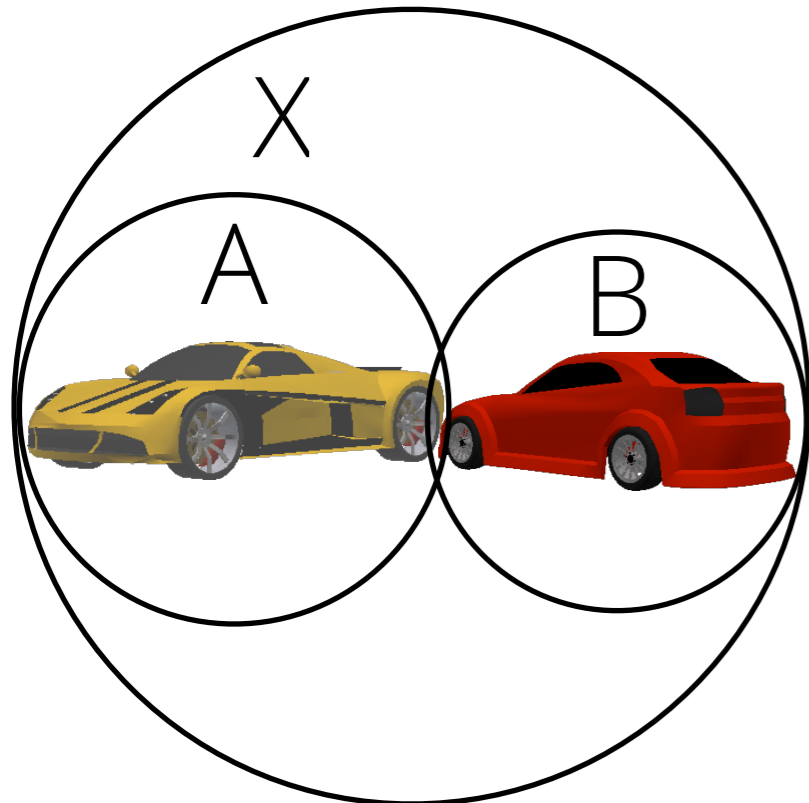
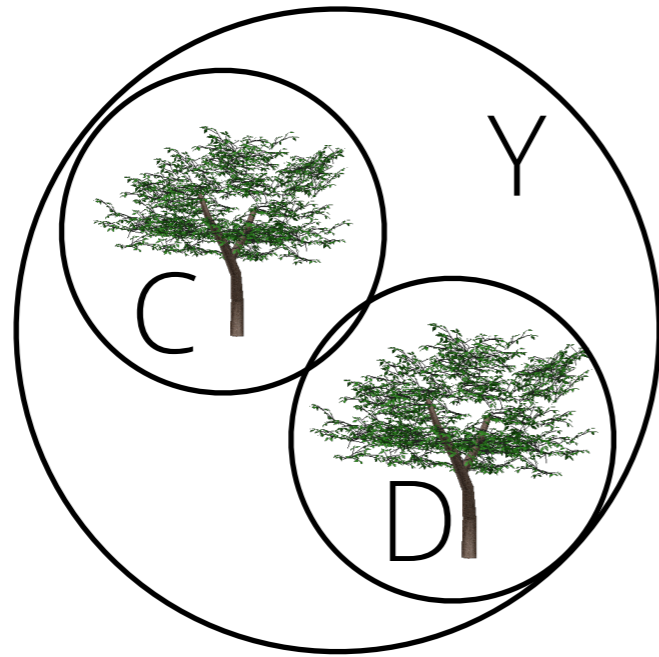
Data Structure - BVH



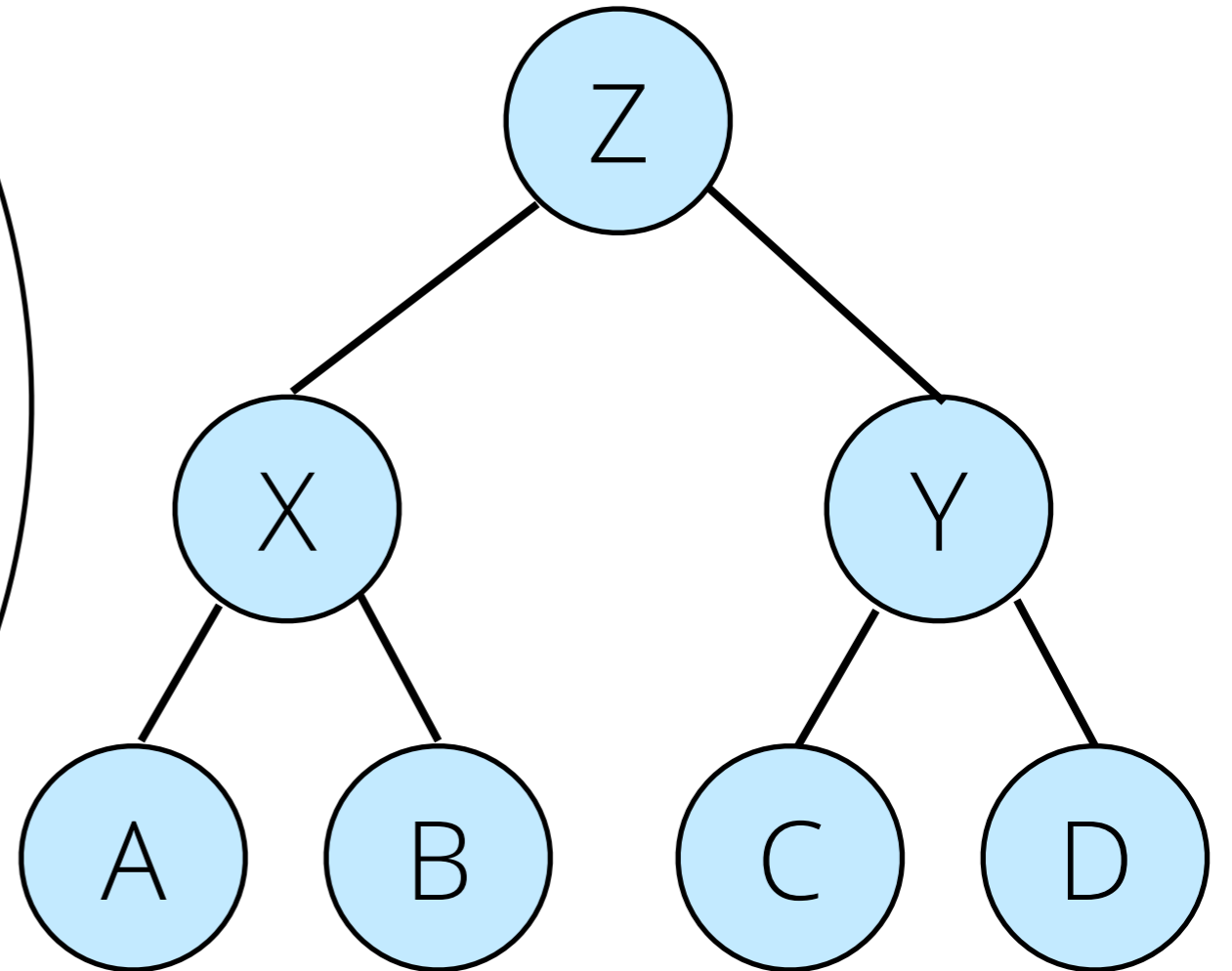
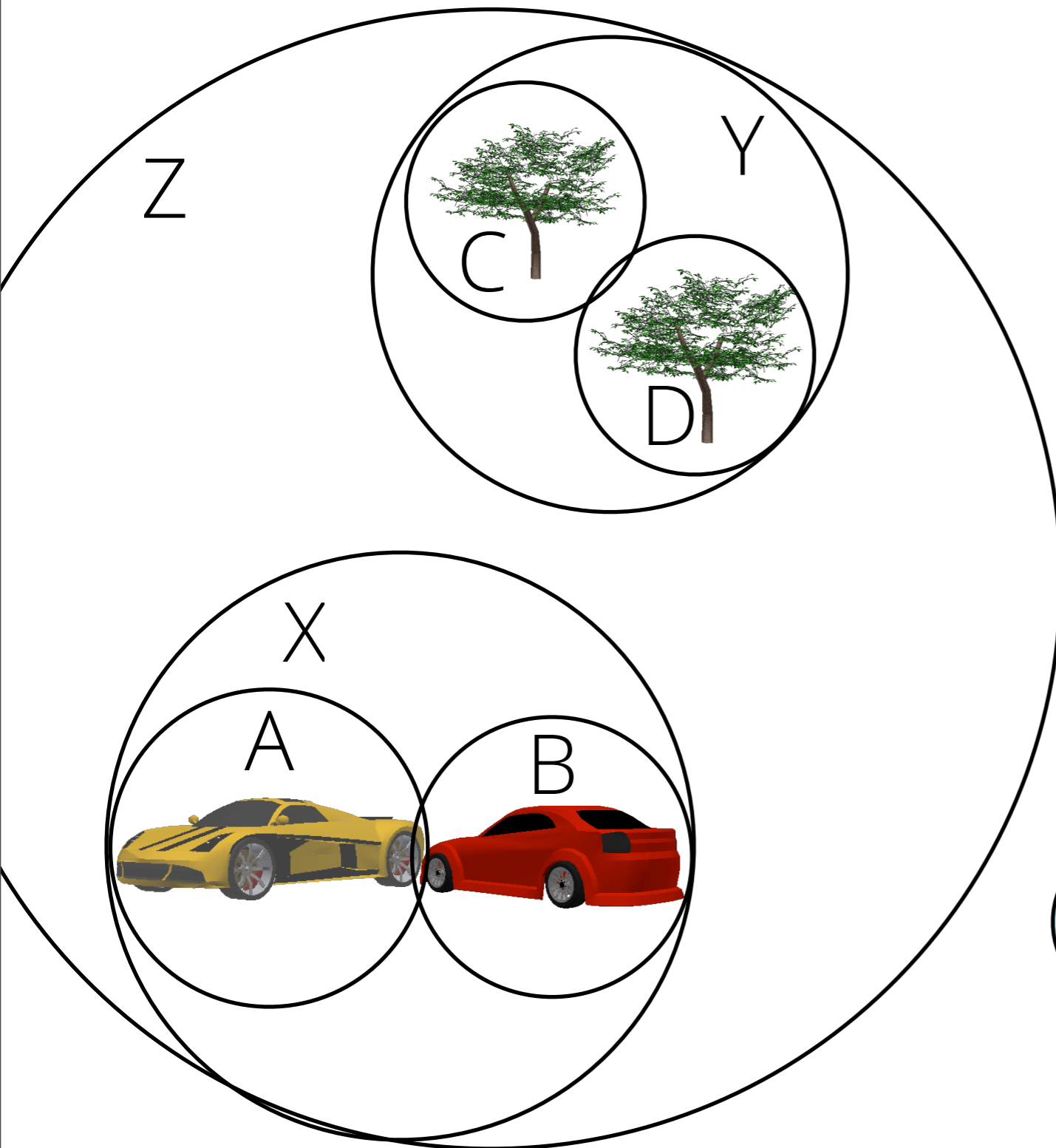
Data Structure - BVH



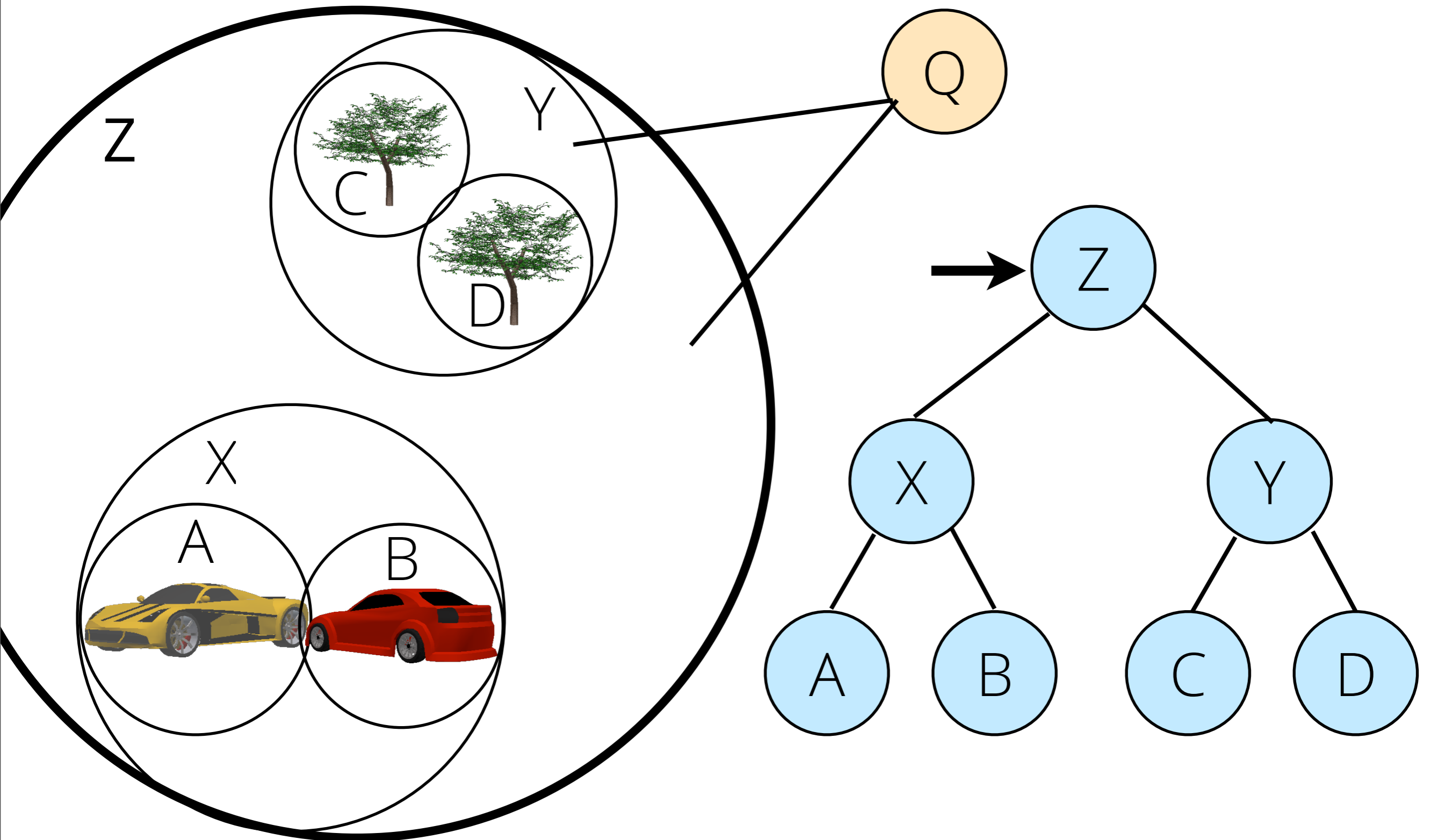
Data Structure - BVH



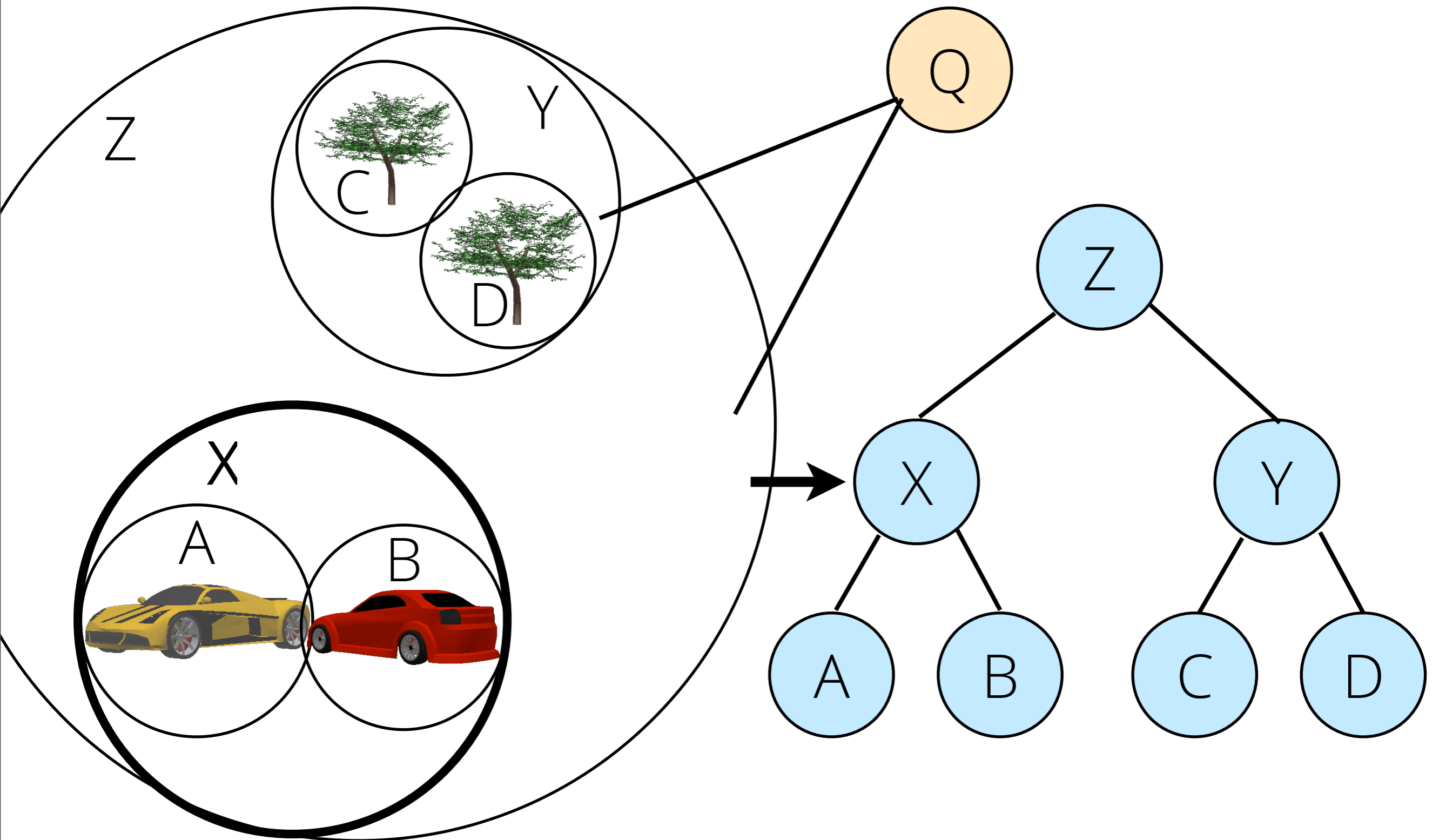
Data Structure - BVH



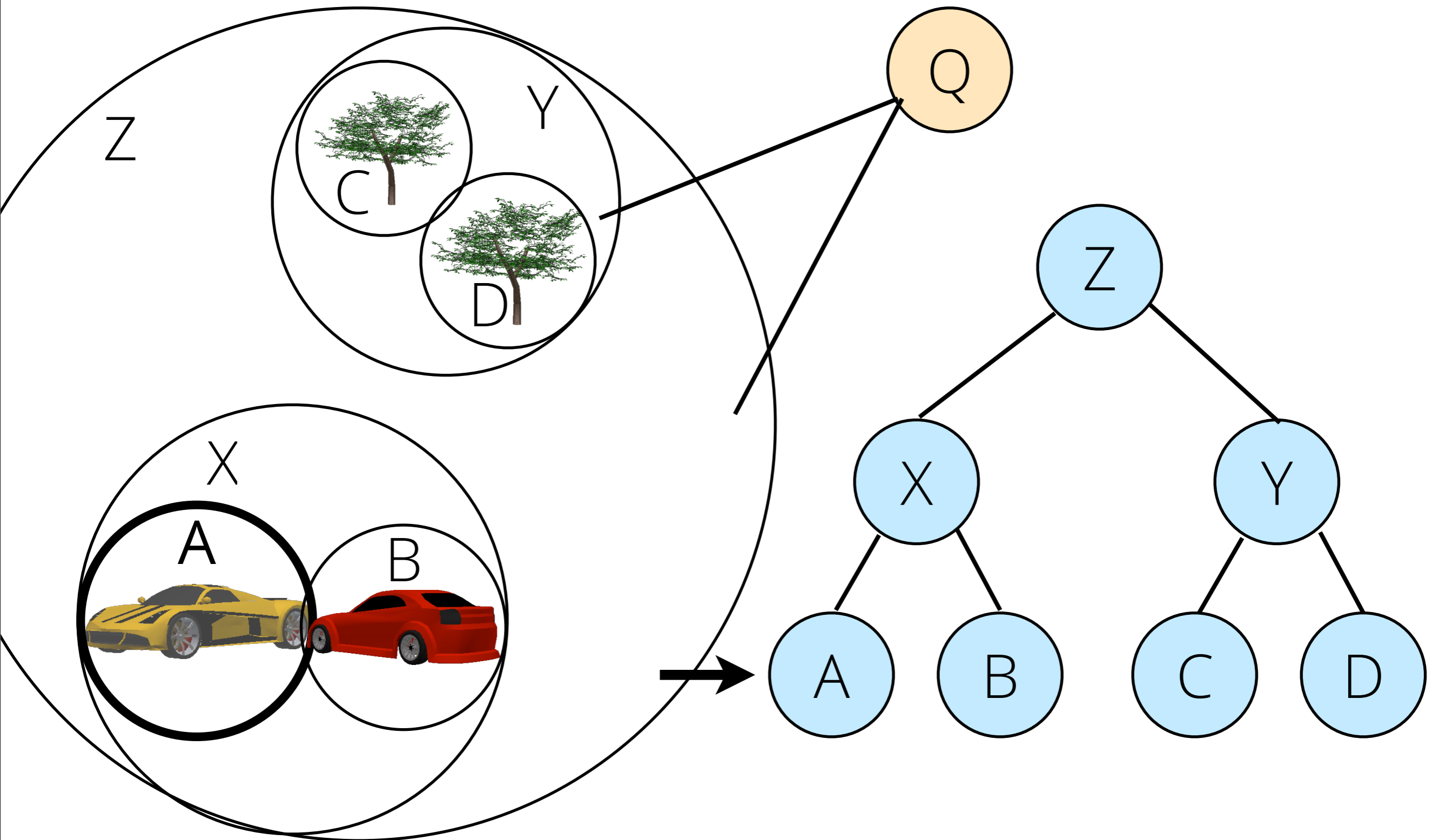
Data Structure - BVH



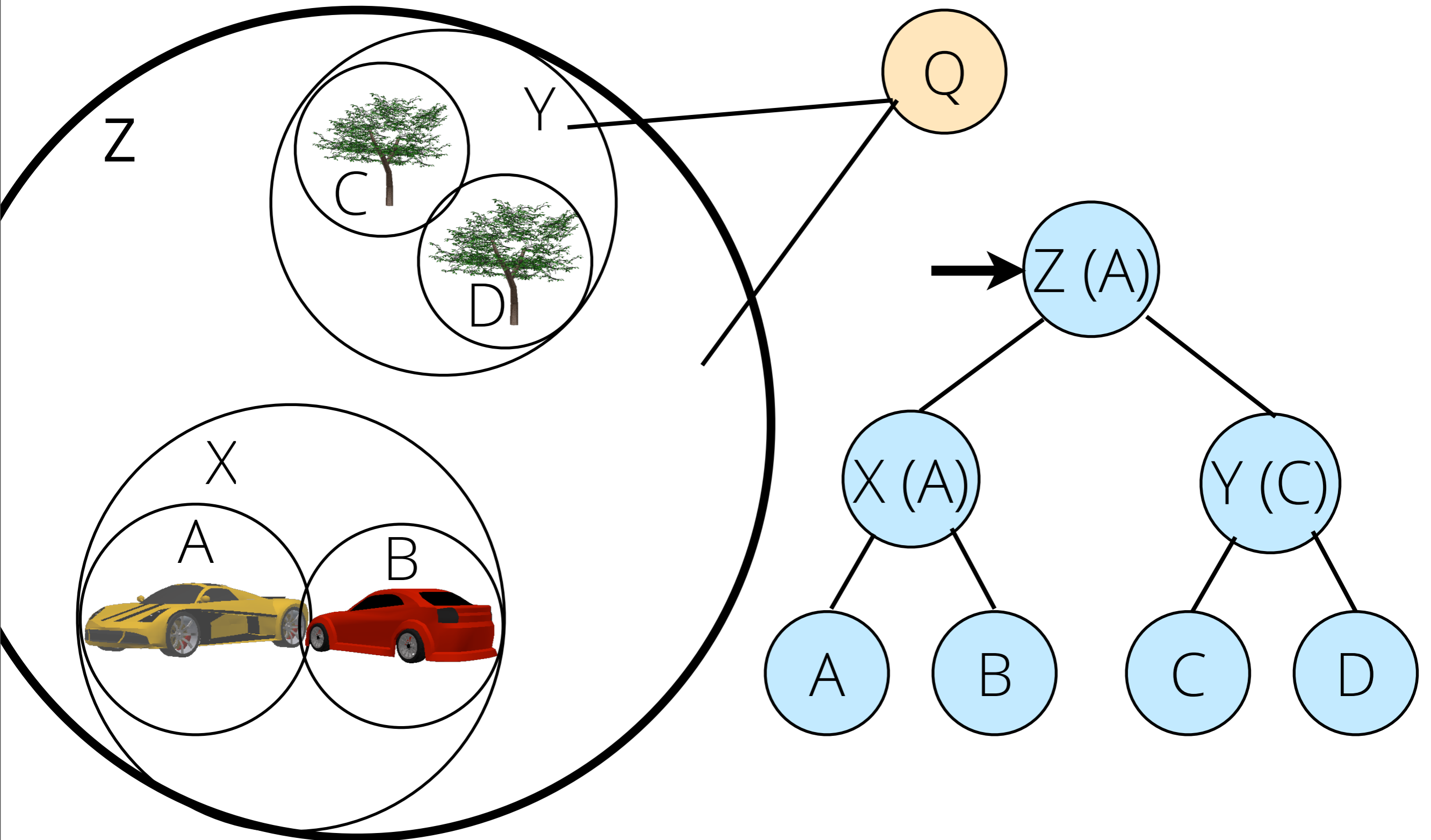
Data Structure - BVH



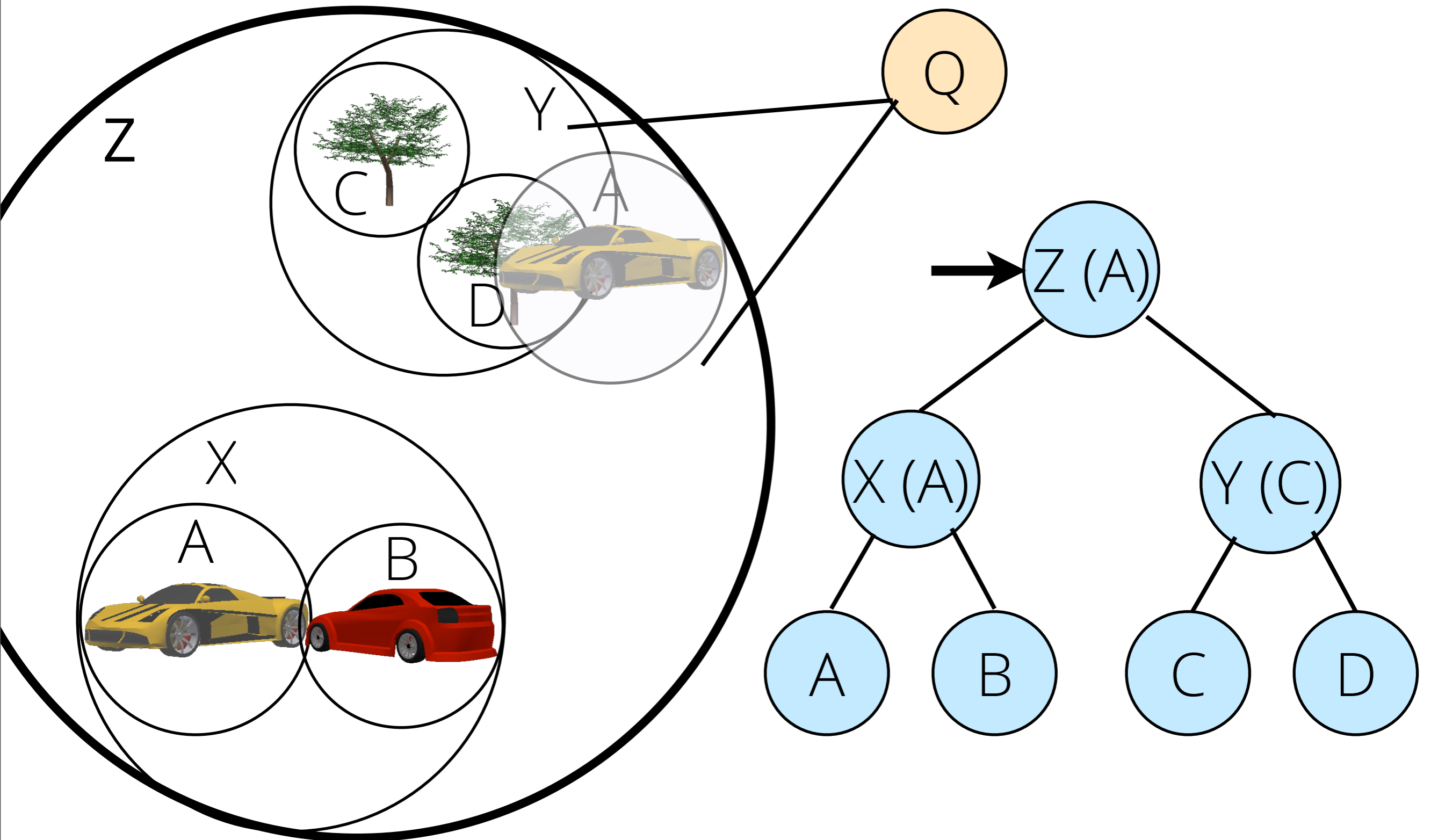
Data Structure - BVH



New Data Structure - LBVH



New Data Structure - LBVH

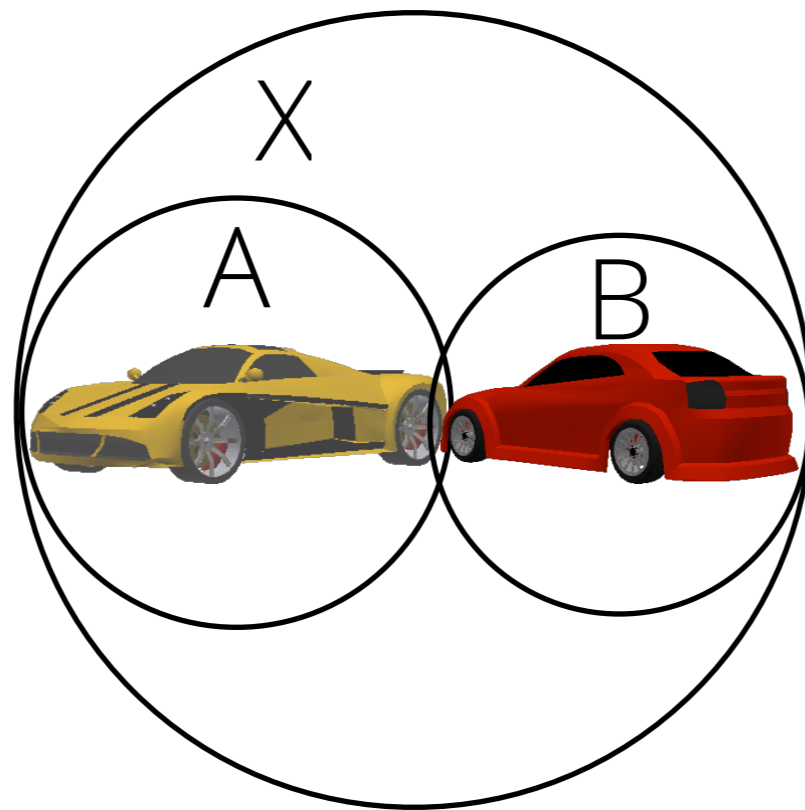


LBVH

75 - 90% fewer nodes tested
than with BVH

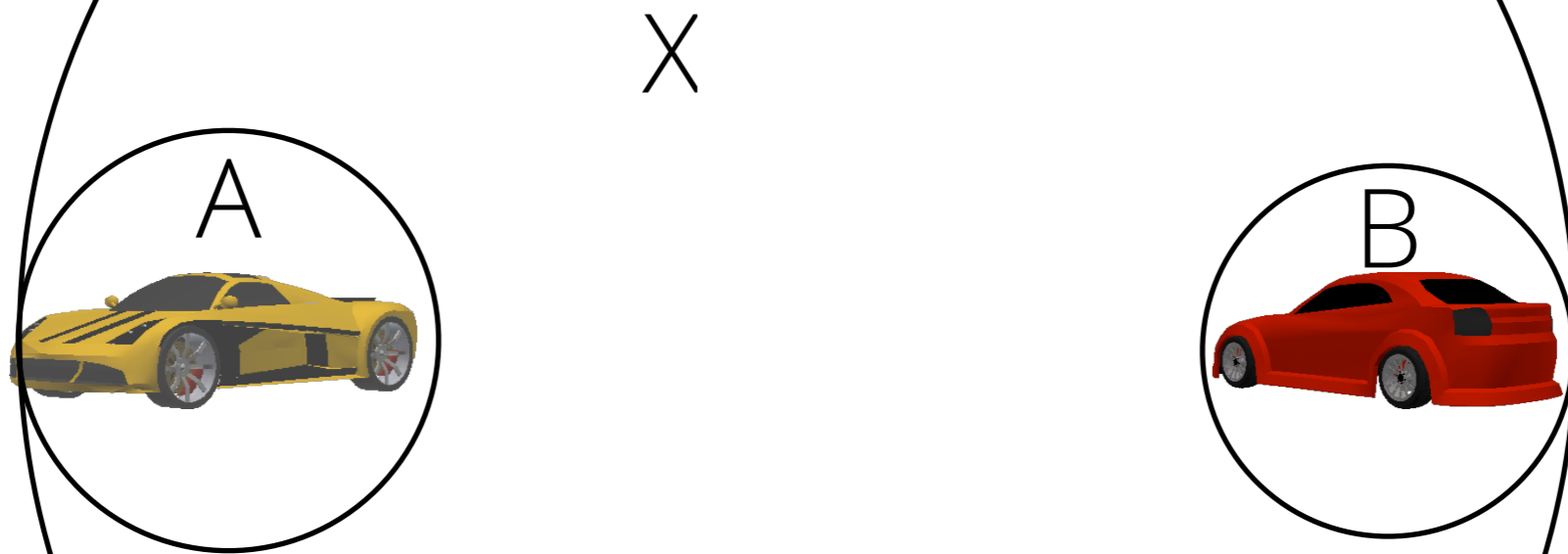
Dynamic Objects

Moving objects make the LBVH inefficient over time

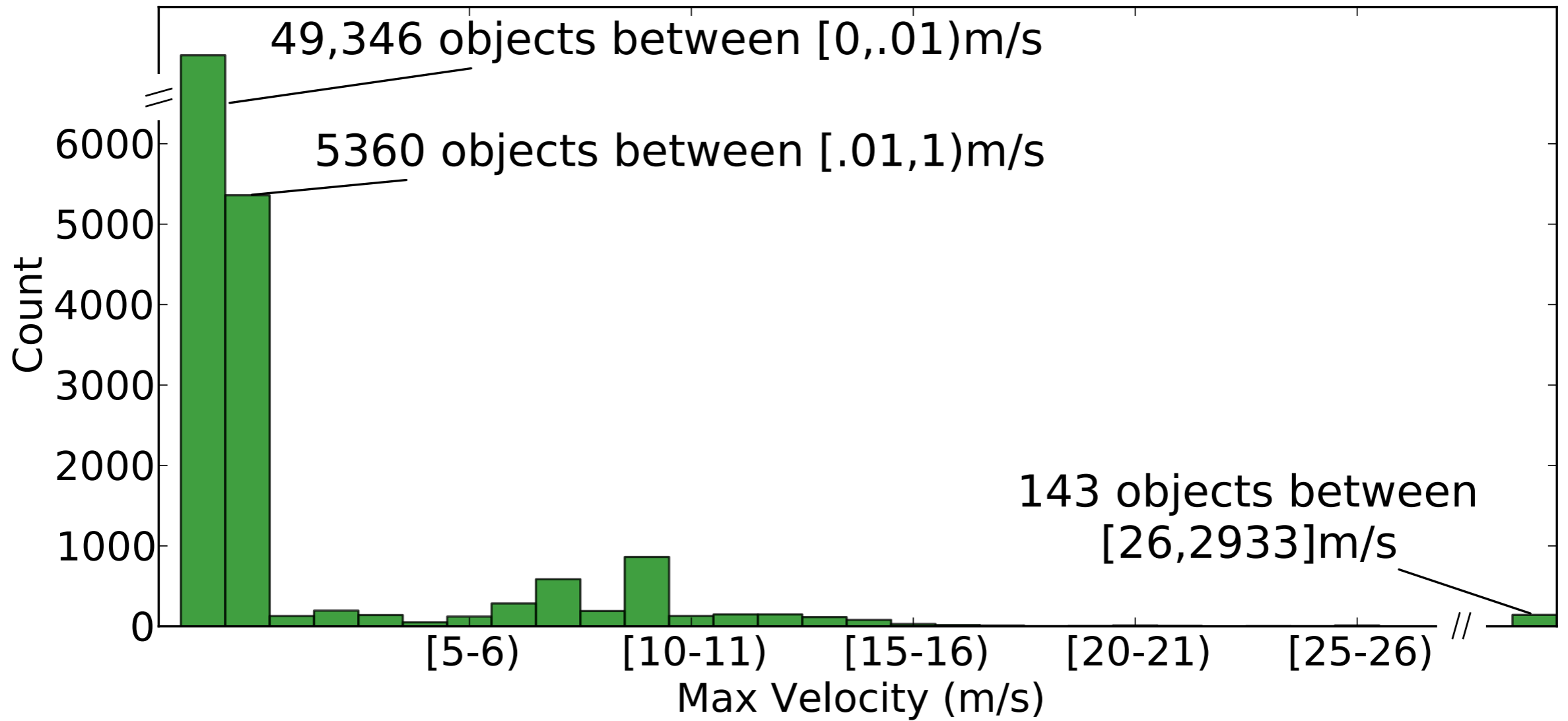


Dynamic Objects

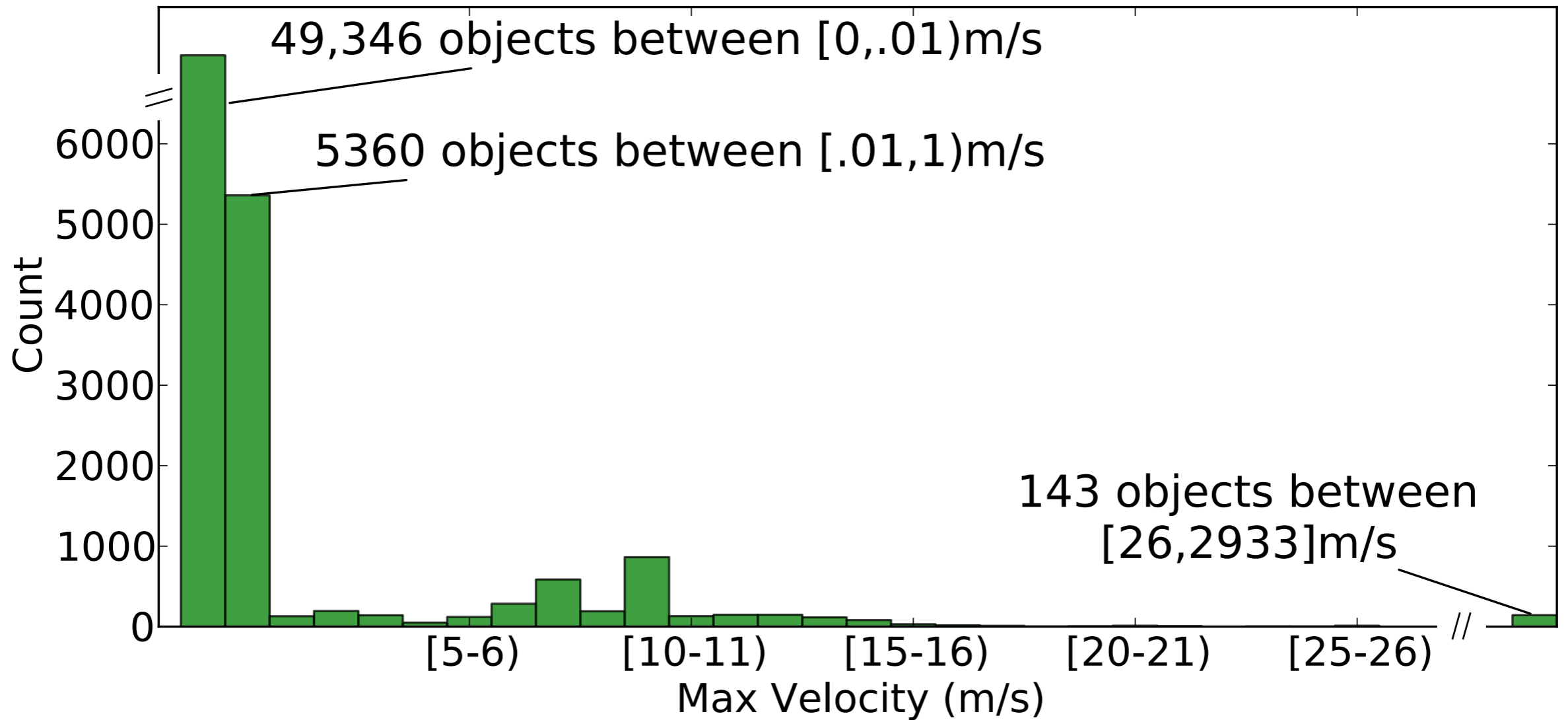
Moving objects make the LBVH inefficient over time



Dynamic Objects



Dynamic Objects



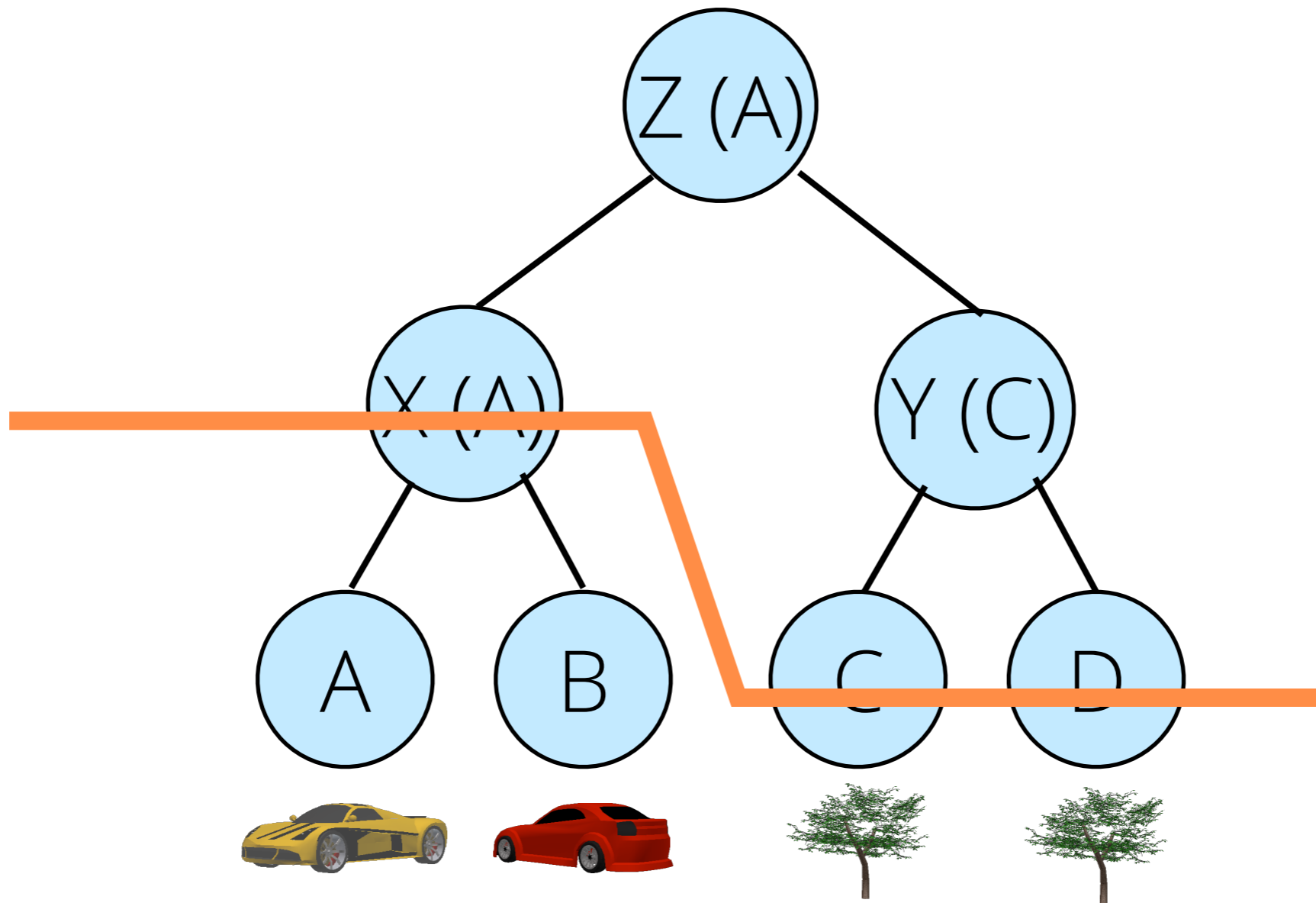
Split between static and dynamic objects

Dynamic Objects

10 - 15% less expensive during short, 100 second experiment

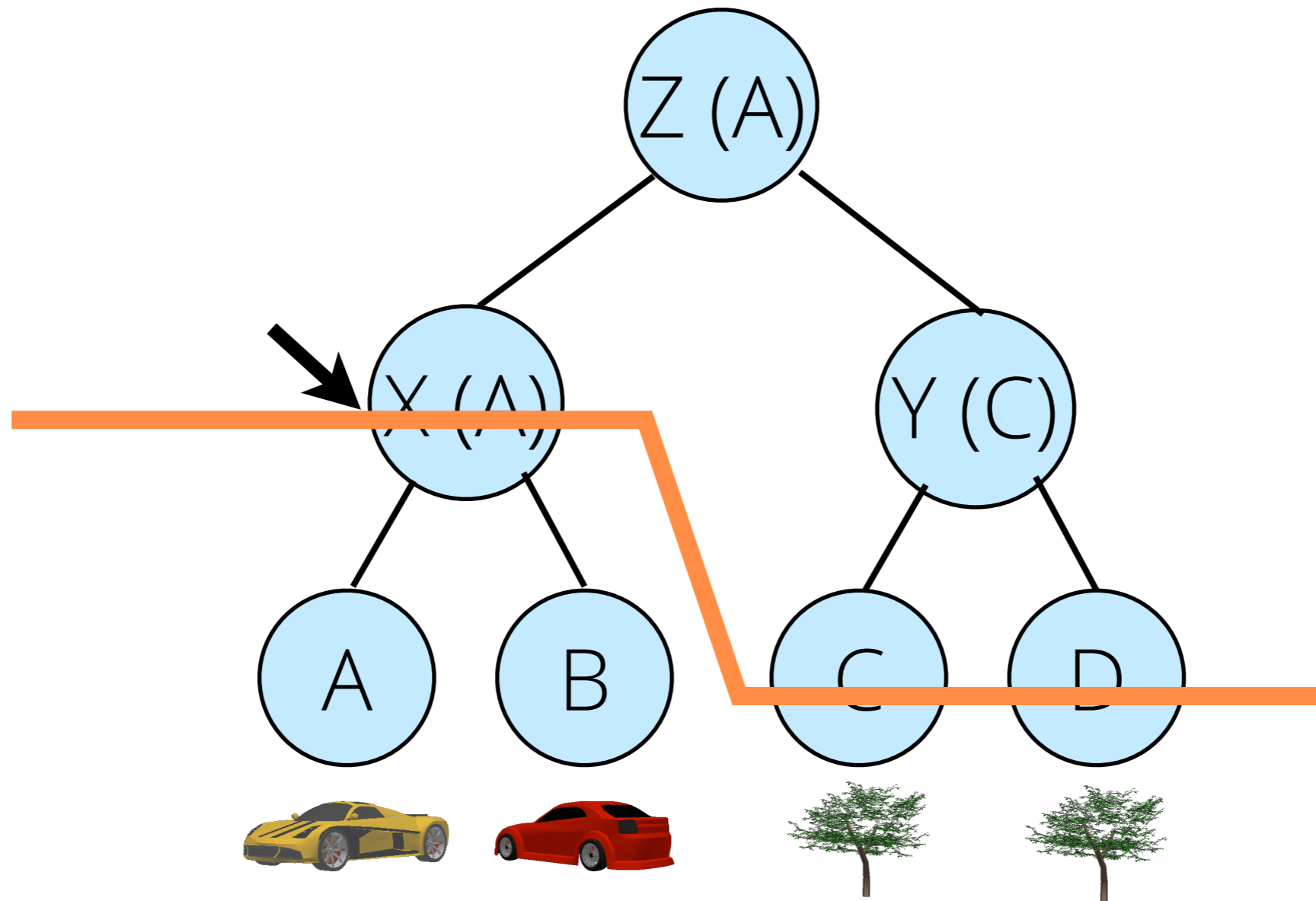
Benefit improves over time

Standing Queries



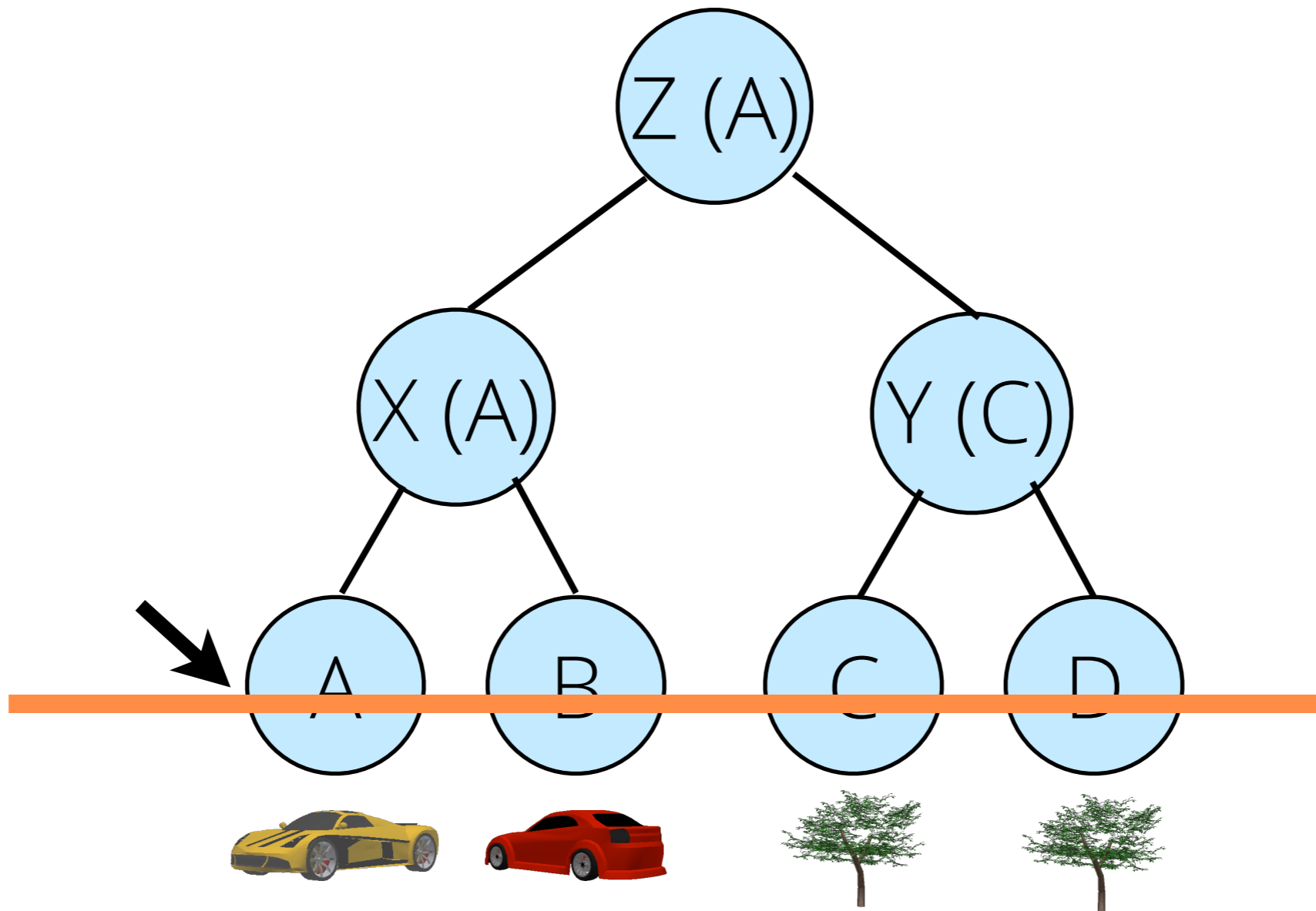
Cuts avoid redundant work

Standing Queries



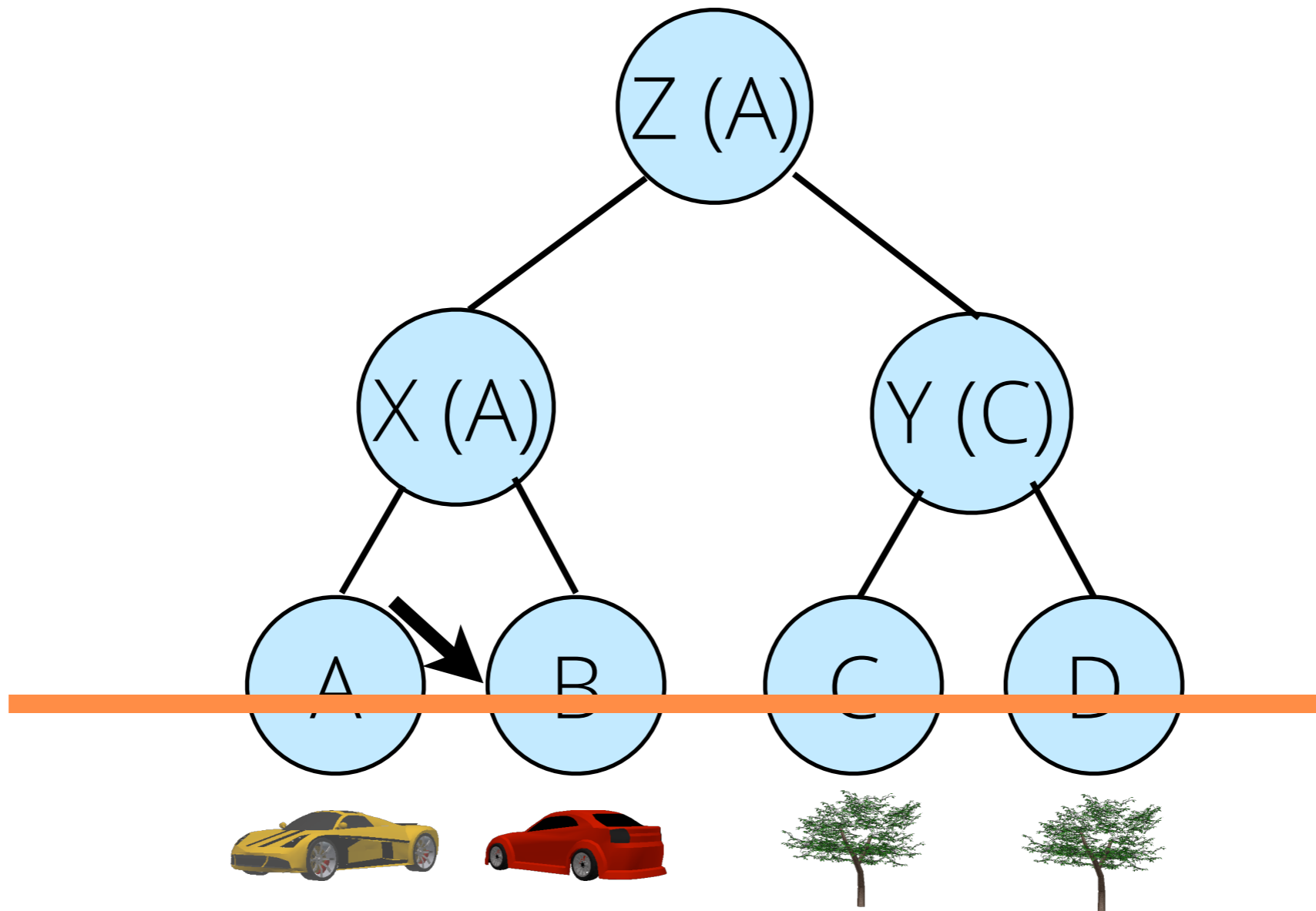
Cuts avoid redundant work

Standing Queries



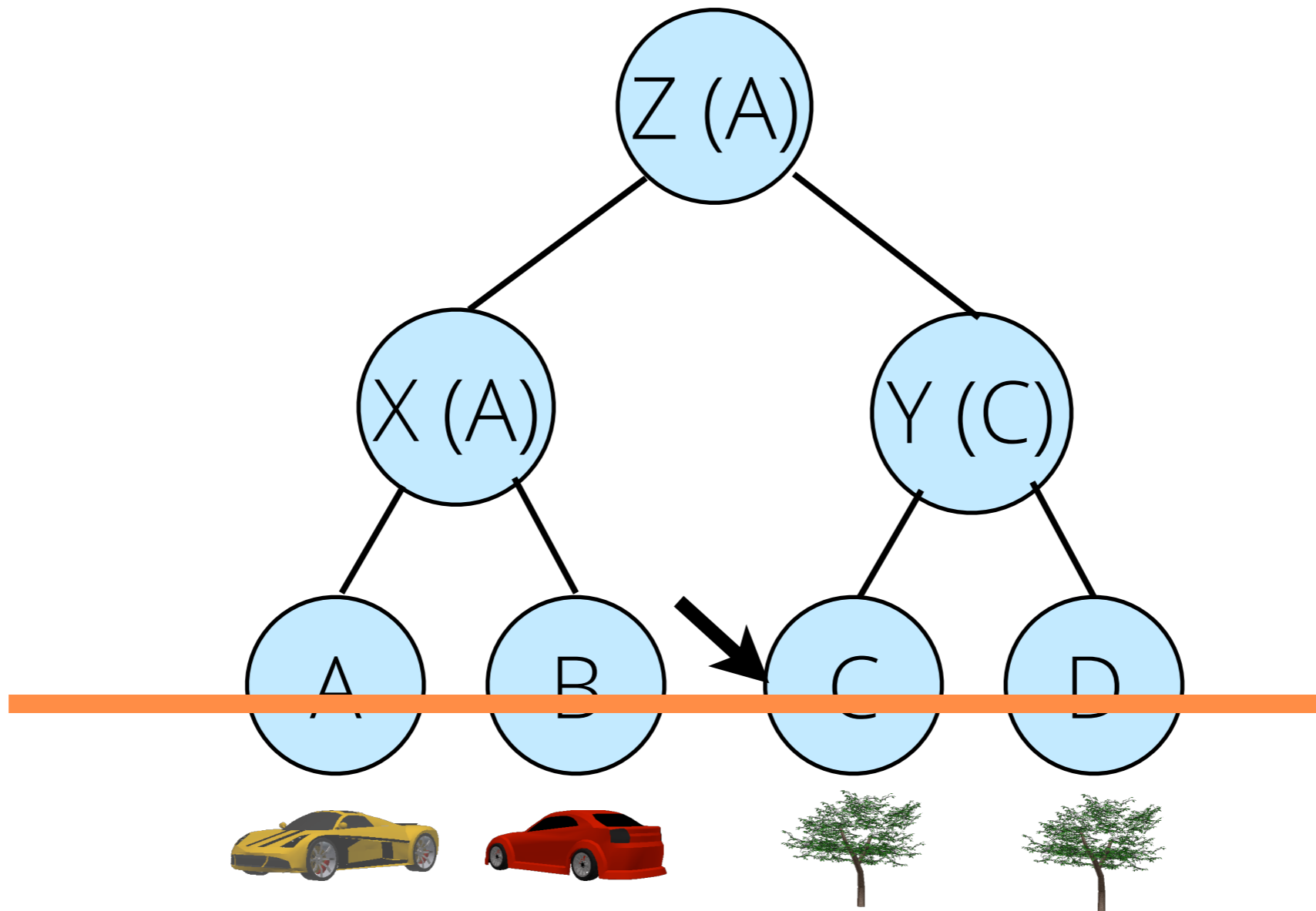
Cuts avoid redundant work

Standing Queries



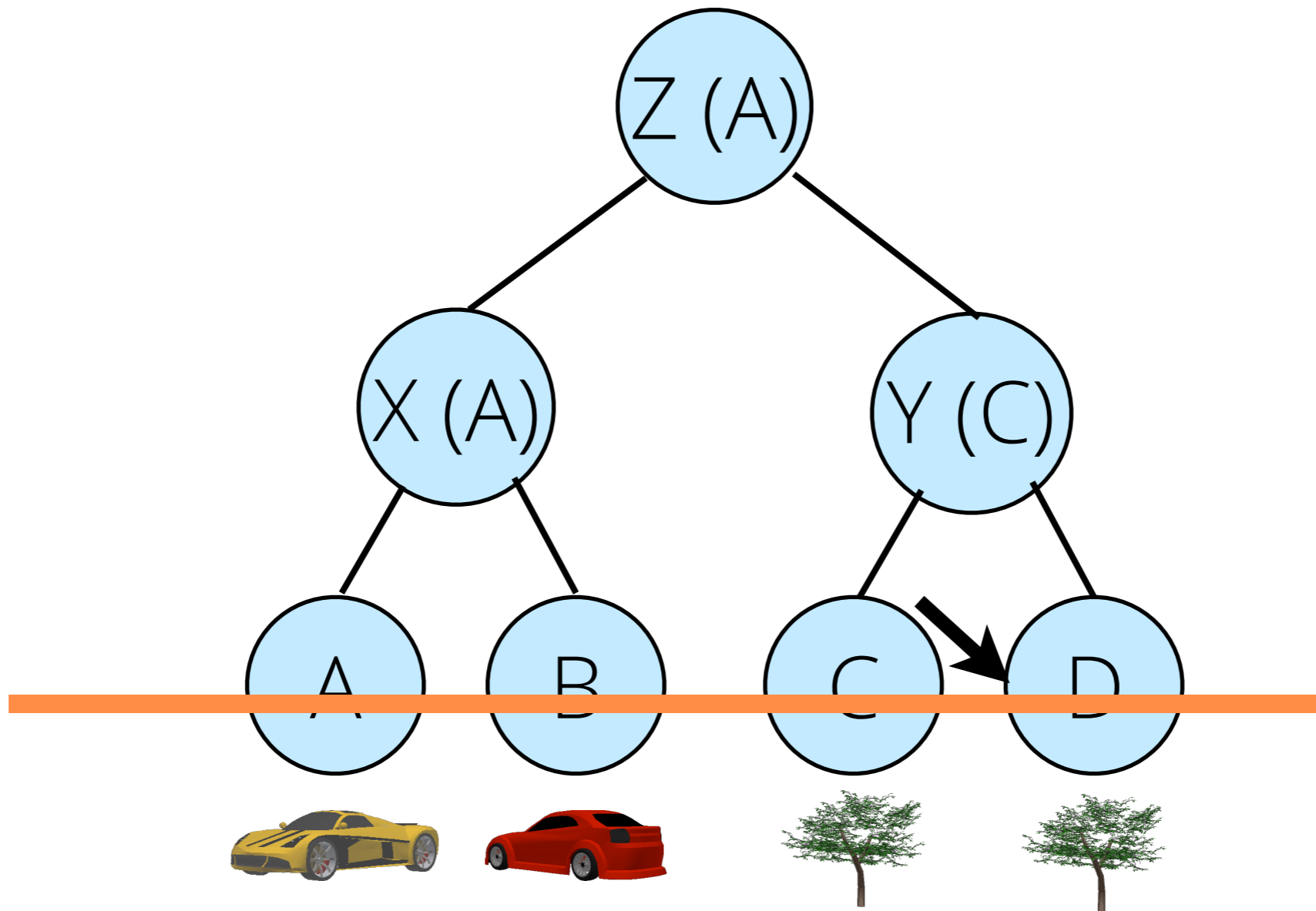
Cuts avoid redundant work

Standing Queries



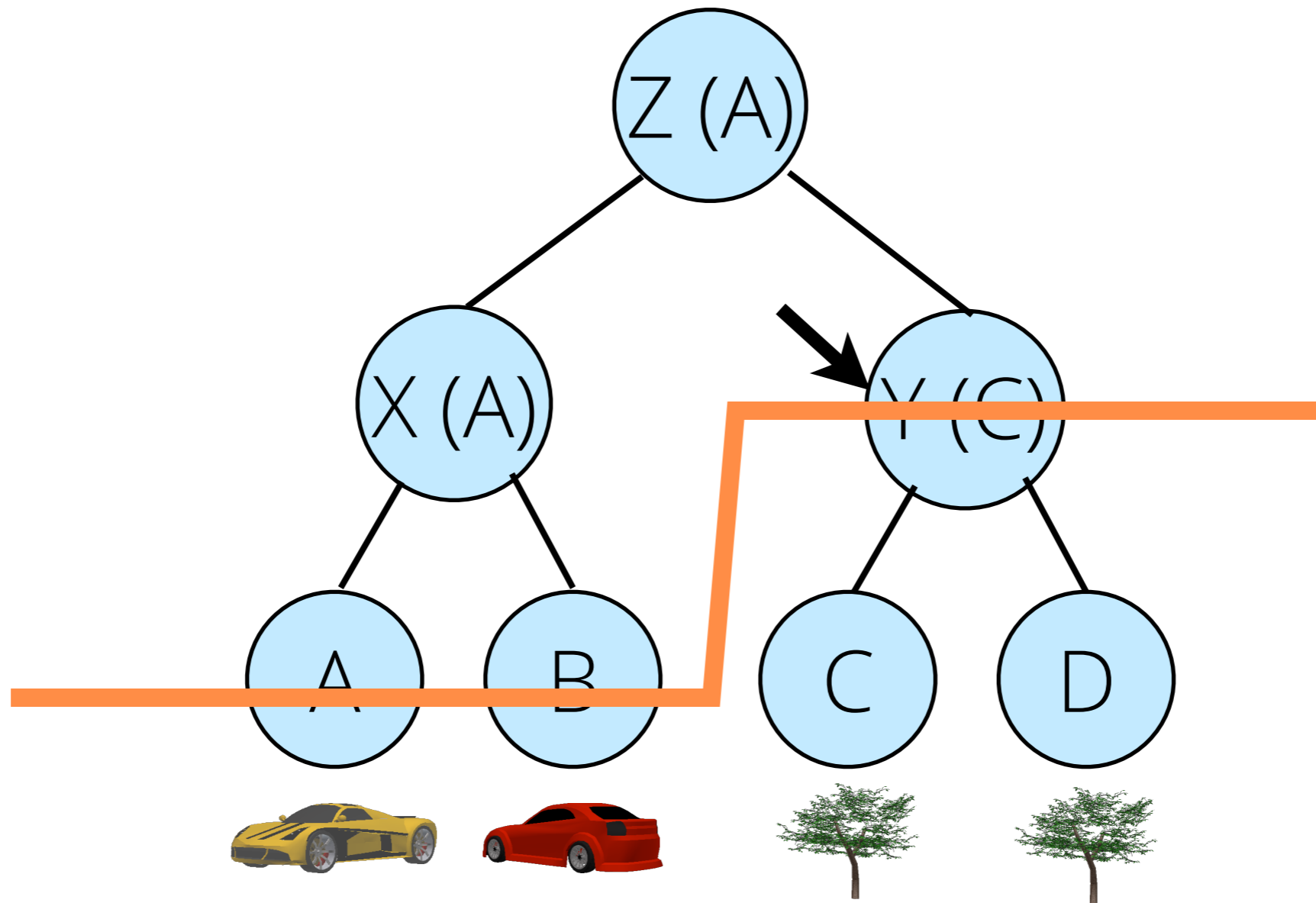
Cuts avoid redundant work

Standing Queries



Cuts avoid redundant work

Standing Queries

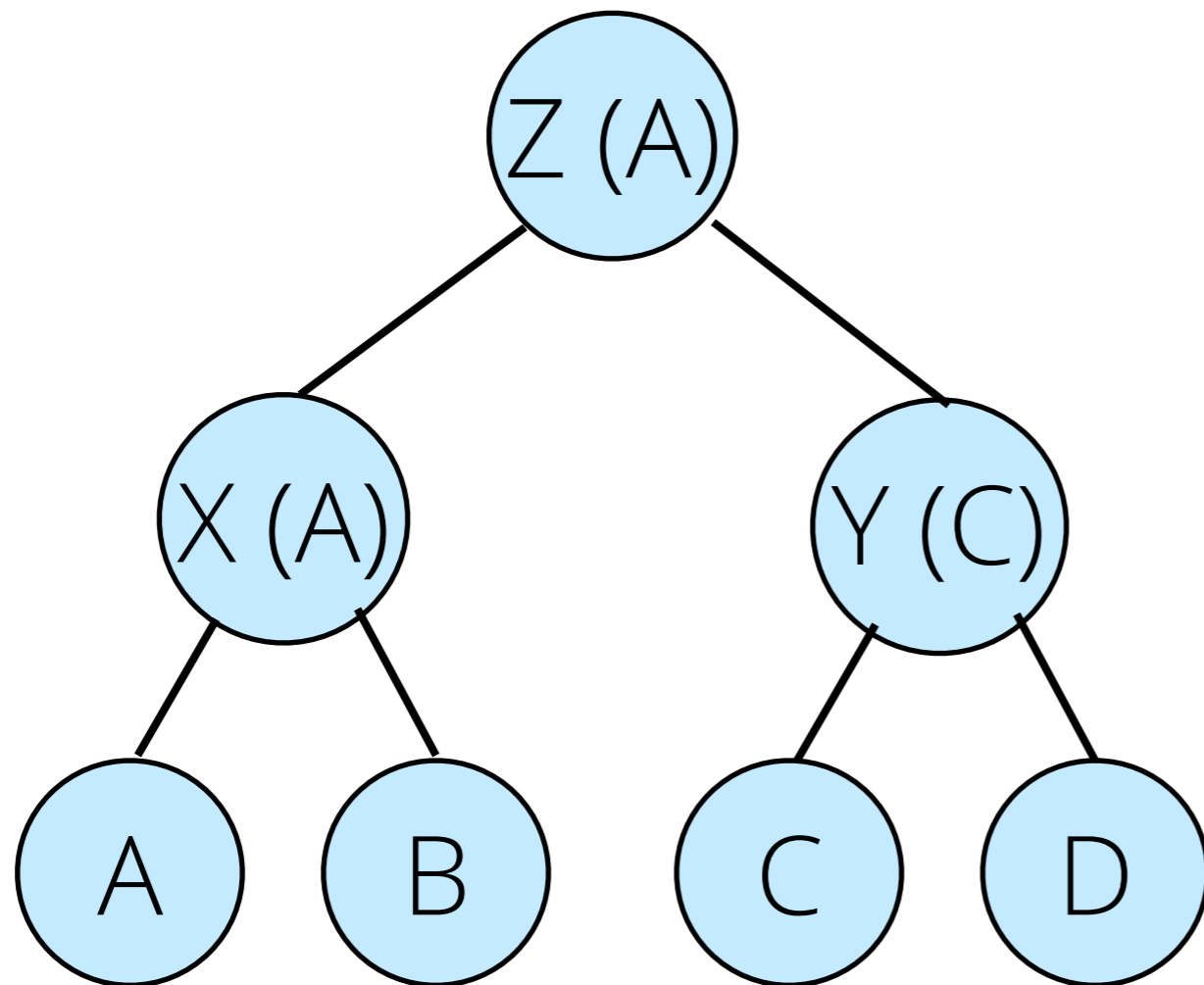


Cuts avoid redundant work

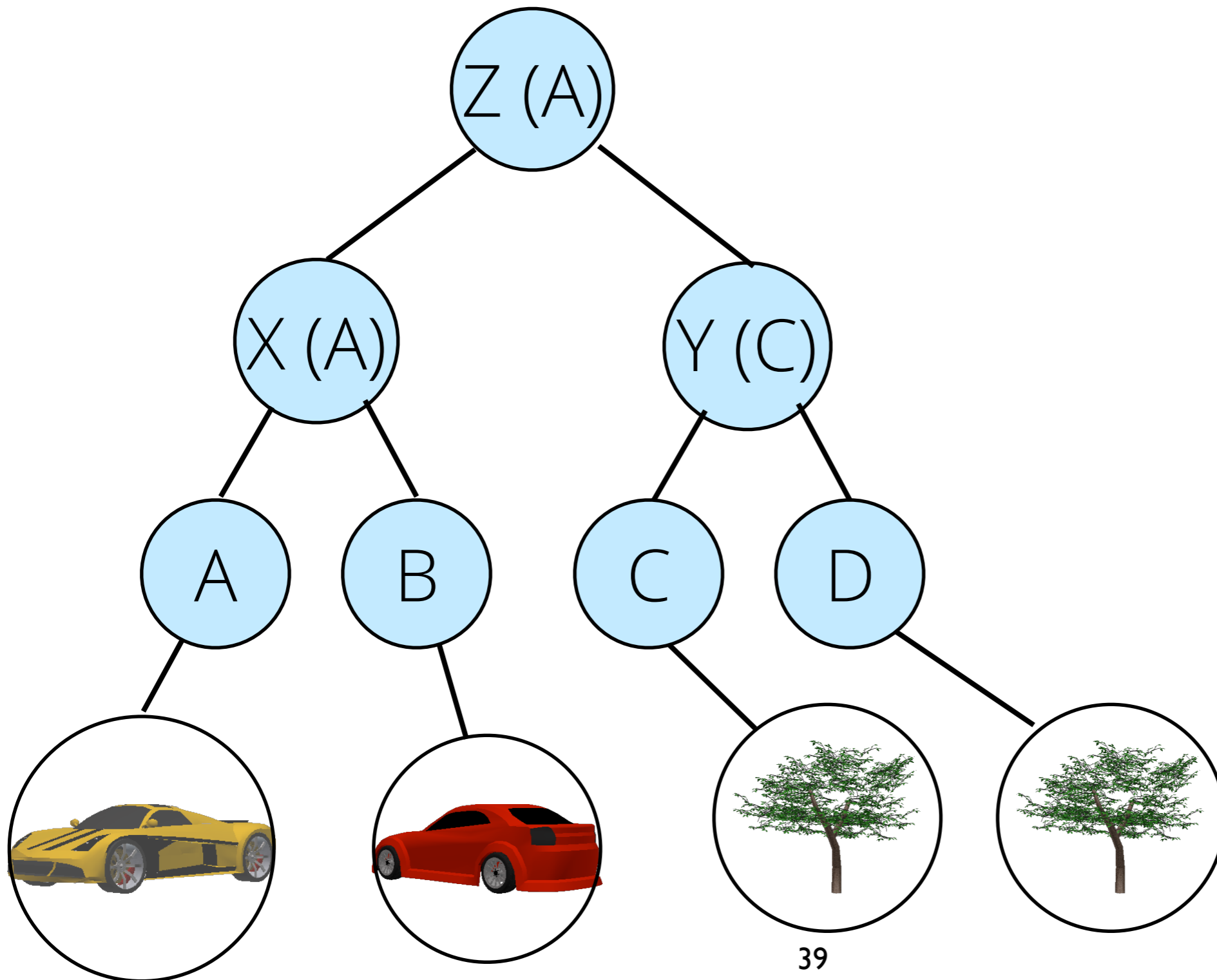
Standing Queries

20 - 56% increase in
query evaluation rate

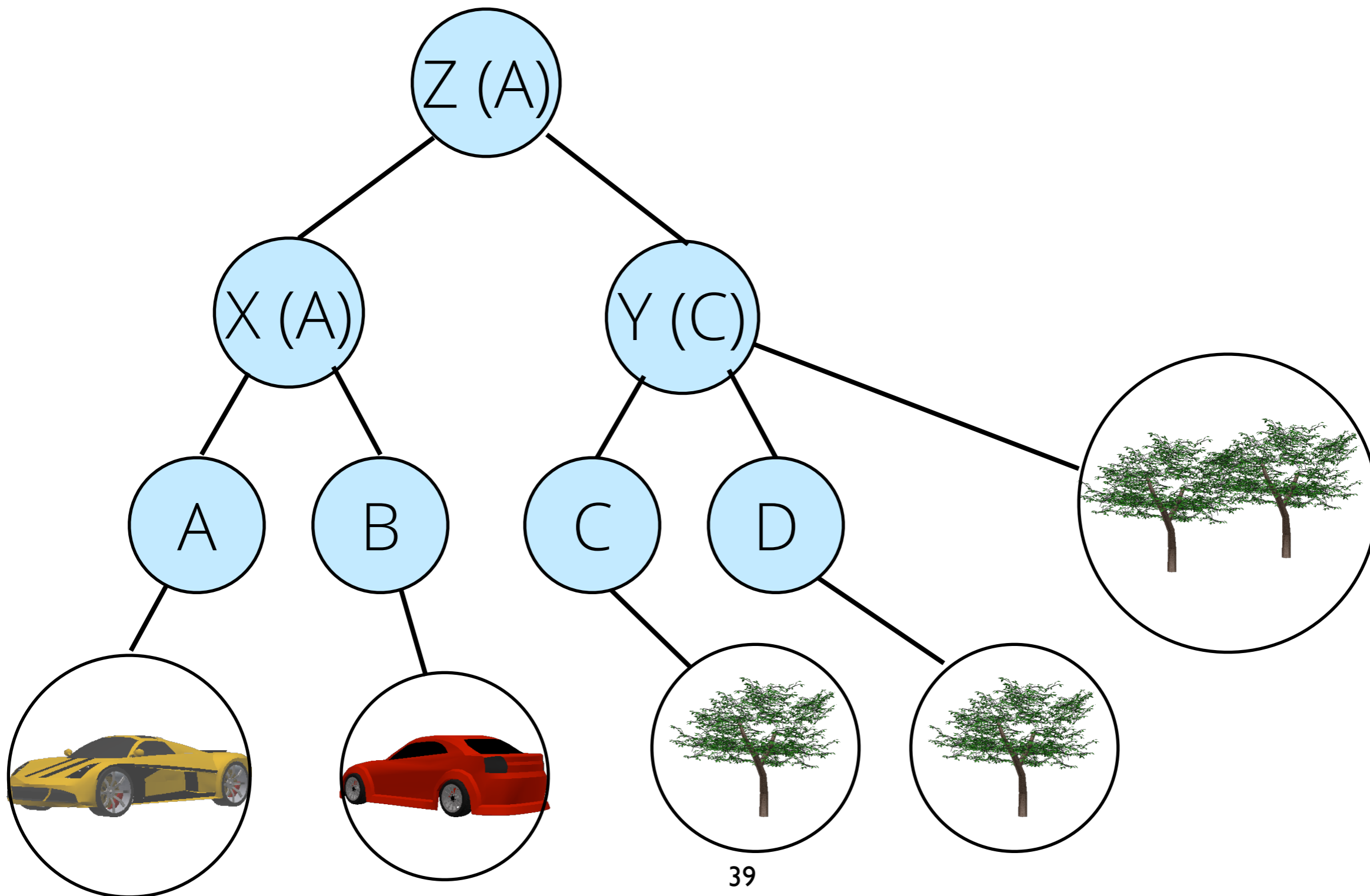
Aggregation



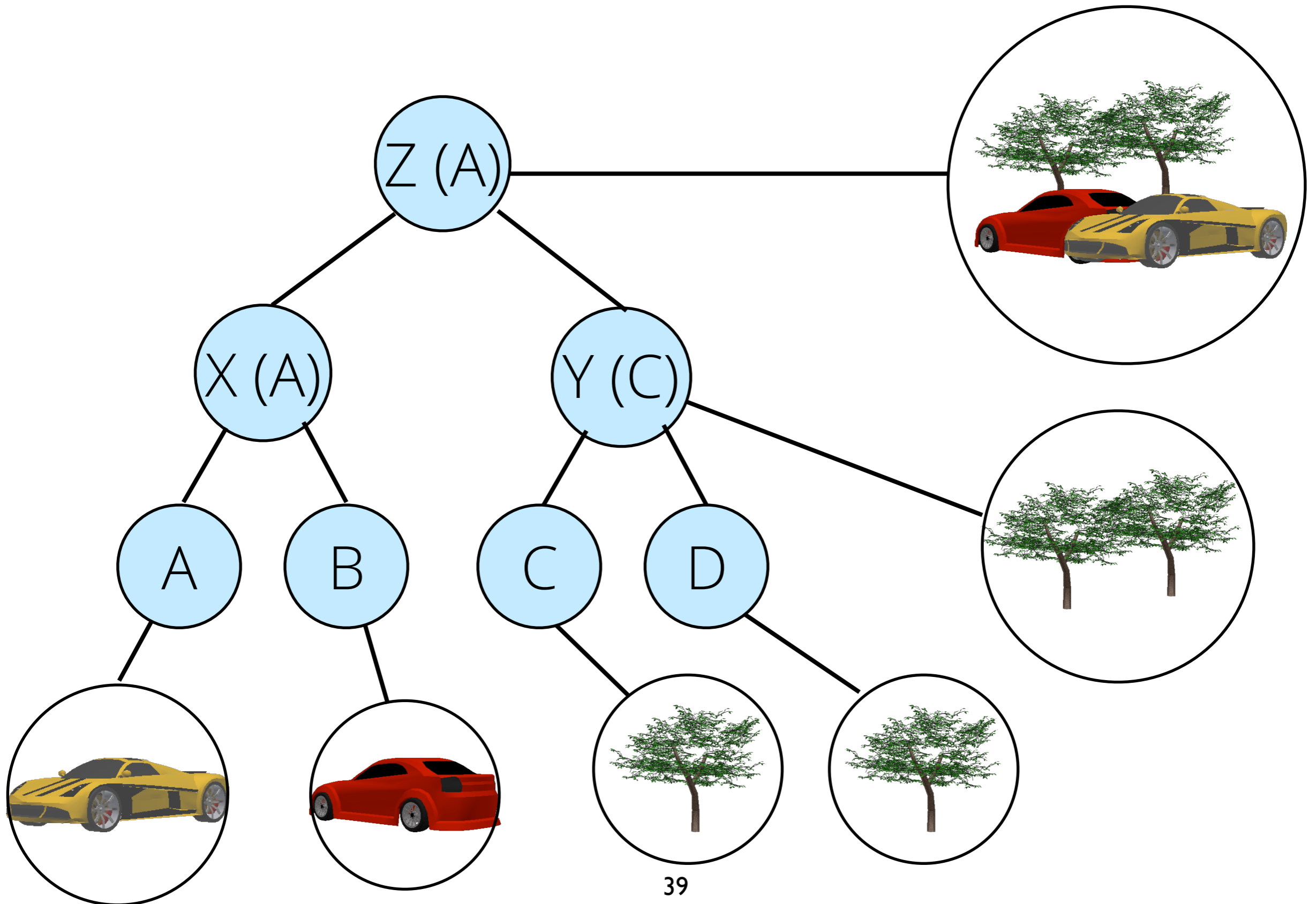
Aggregation



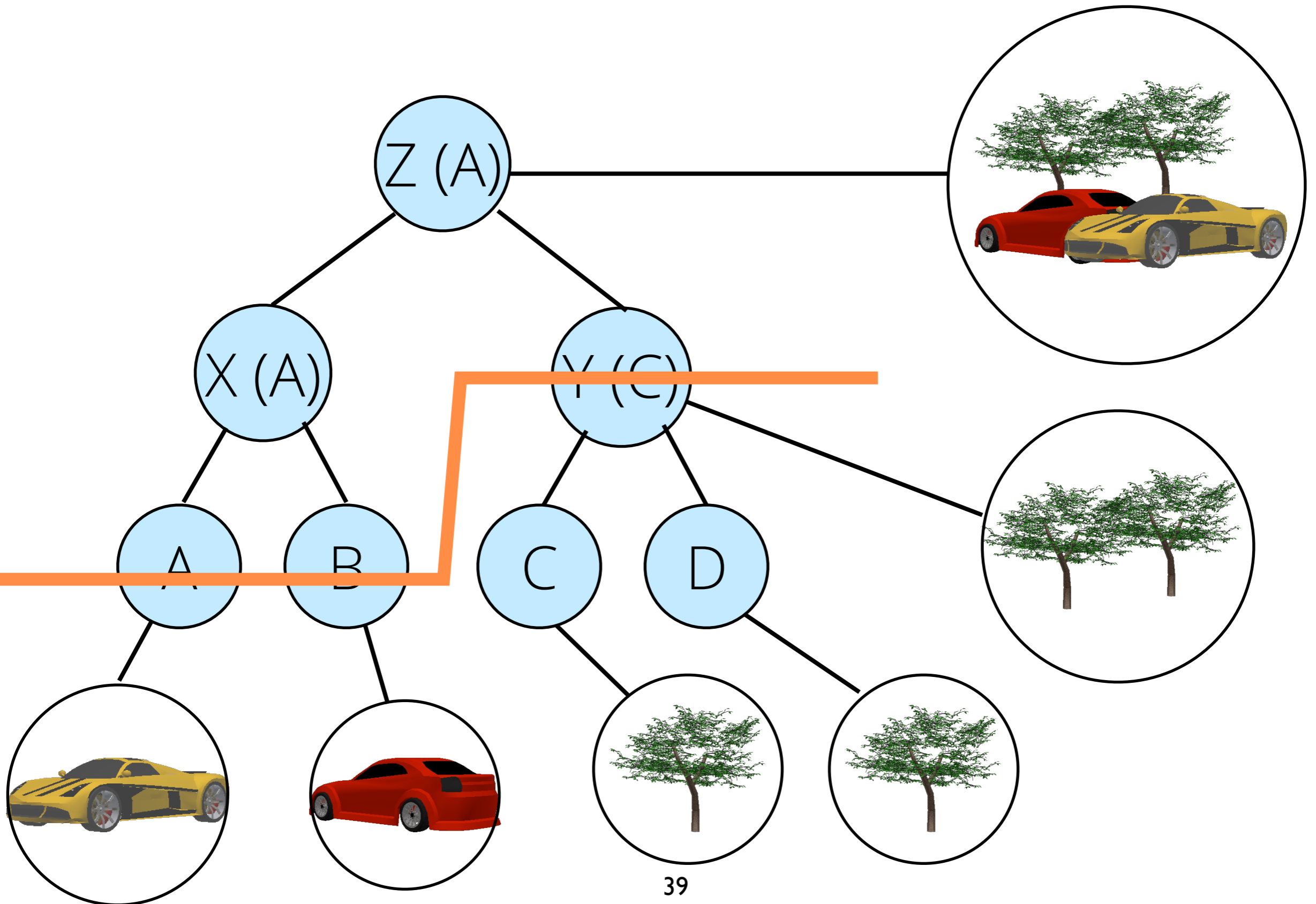
Aggregation



Aggregation



Aggregation



Aggregate Queries

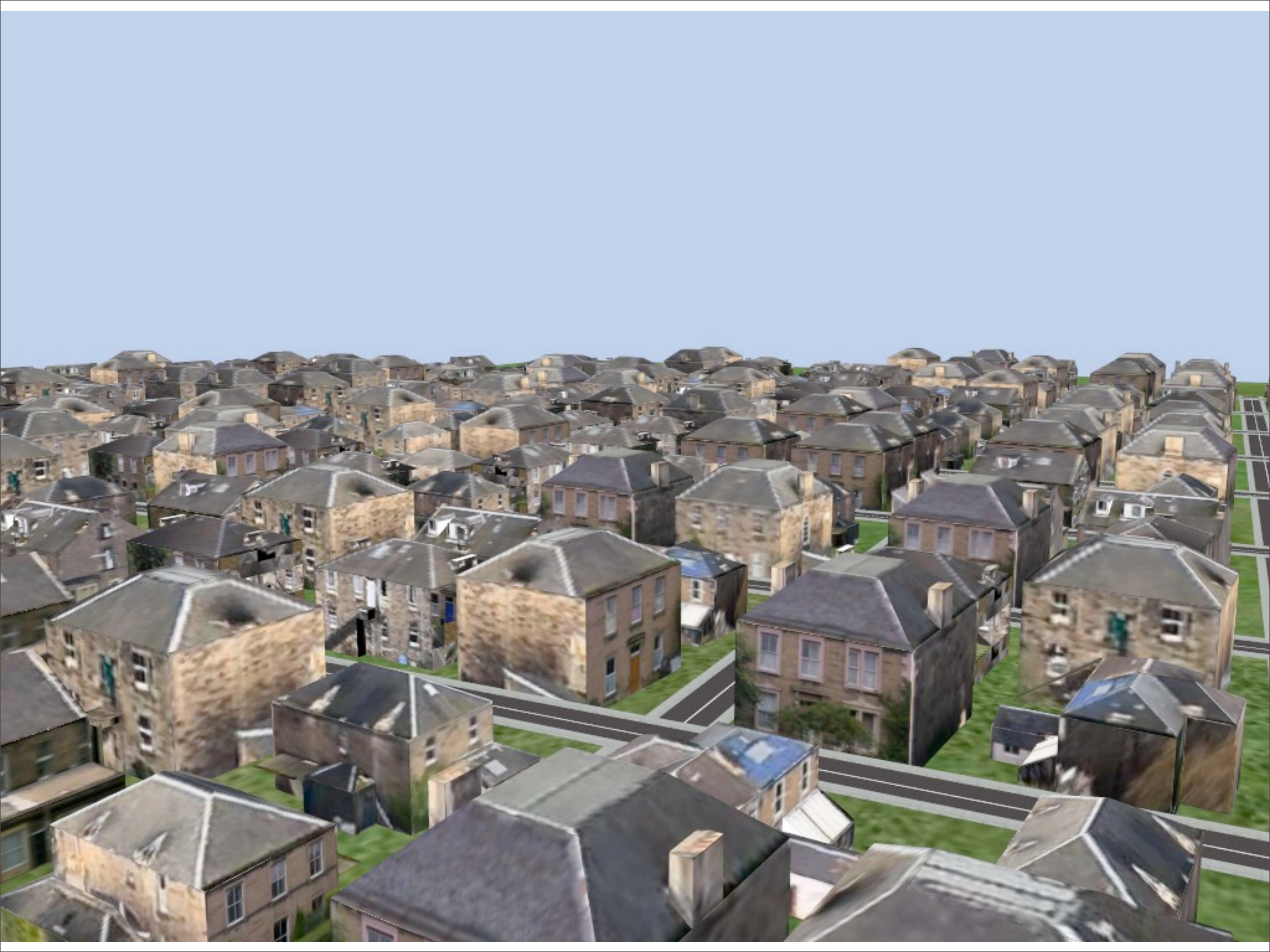
- Queries on a server are all similar
- Aggregate queries to reduce inter-server querying load
- Filter results further before returning results to querier

Server Discovery



Server Discovery

- Geometric server discovery
- Determine which other servers need to be queried
- Built on same LBVH data structure

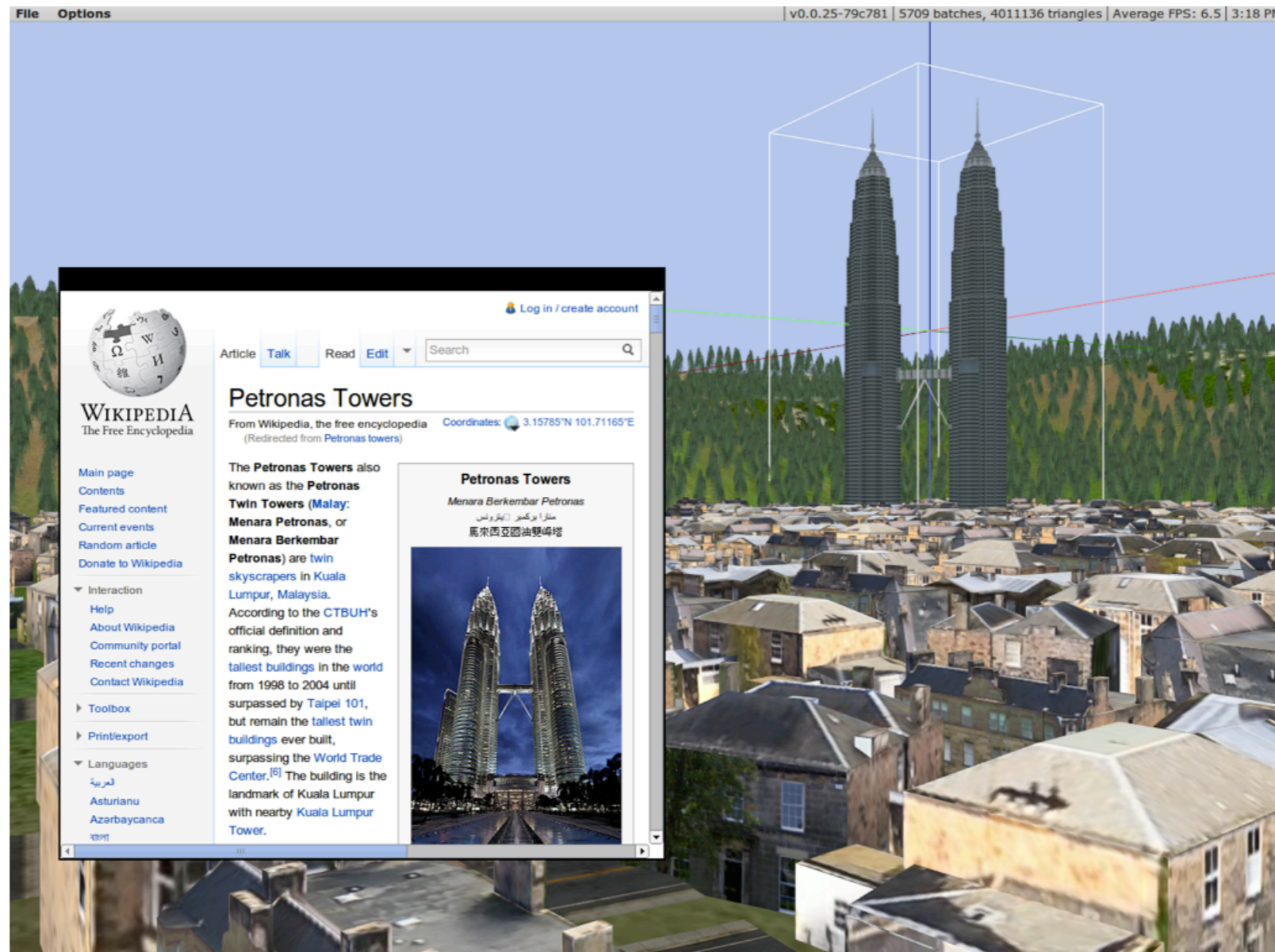




Also in the Paper

- Globally consistent distributed data structure mapping regions to servers
- Global routing table enabling all-pairs communication
- Forwarder with intuitive, physically-based weighting emphasizing local traffic

Wiki World



Automatically find information about objects on Wikipedia

But wait, there's more...

There are many more systems challenges at the intersection of systems, graphics, PL, databases, ...

A few examples:

- Audio: distant siren, roar of a crowd
- Efficient property updates

Thank You

Download and code at

sirikata.com

Questions?