Using Trees: Spatial Trees and Searches

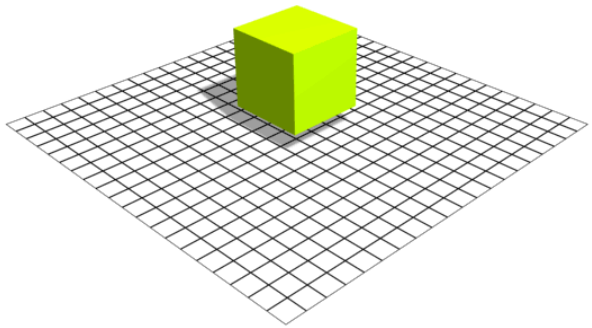
(slides based on those of Han-Wei Shen and also of MIT CS Lab)

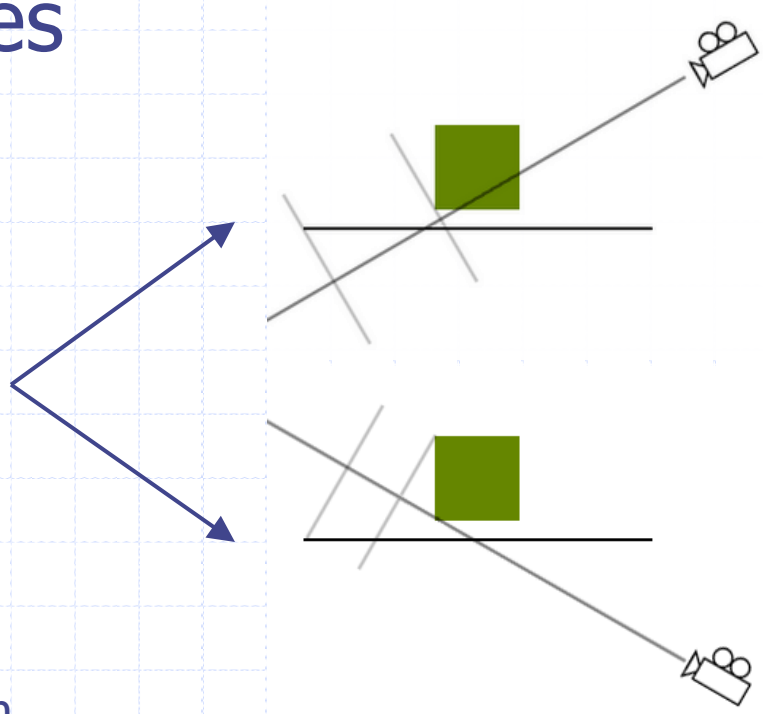
Motivation

- Sorting objects front to back to rendering
- Nearest-Neighbor Searches
- Correspondence Searching in Range Image Registration
- What's Wrong with Brute Force?

Sorting Objects

- Fundamental operation for rendering synthetic scenes



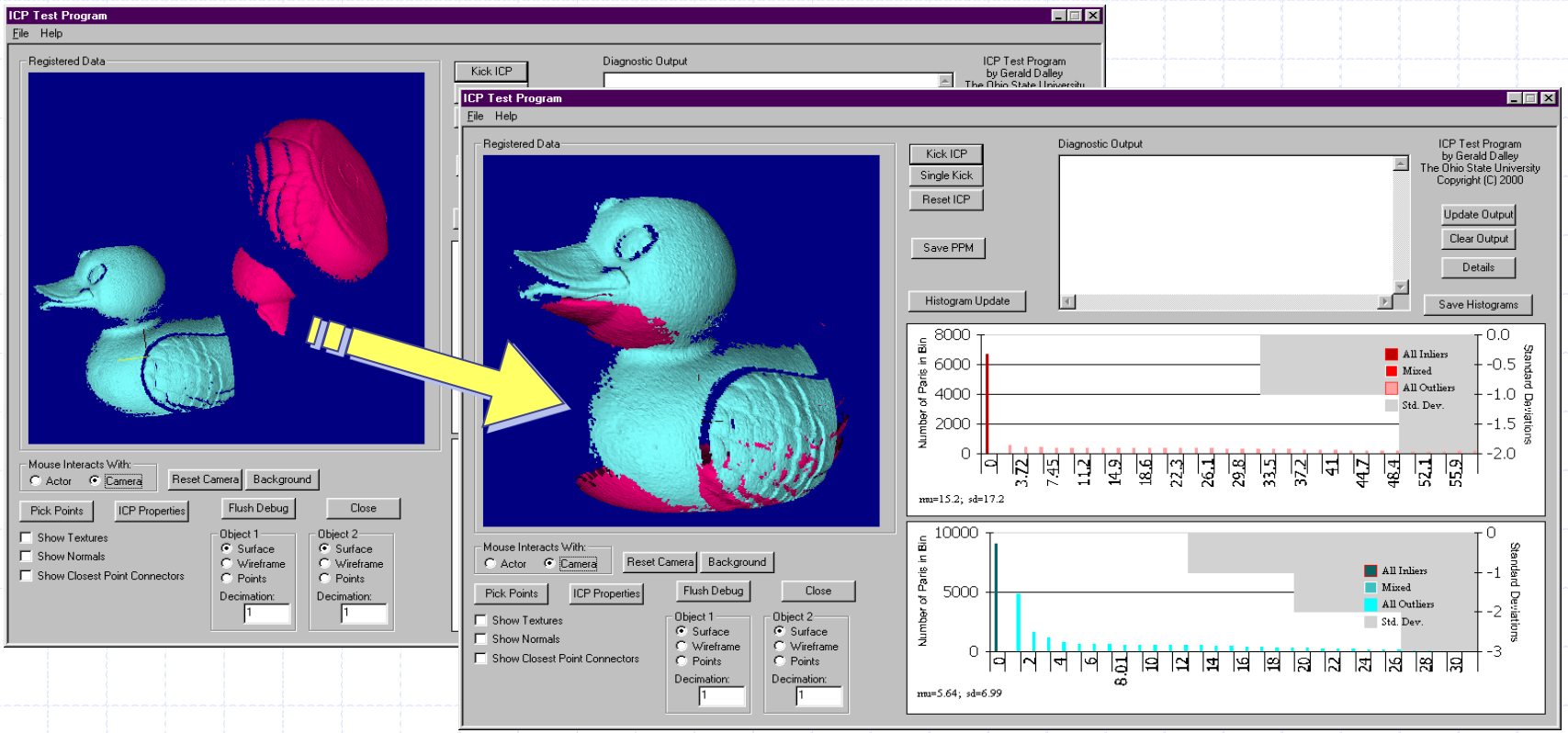


What should be rendered at each pixel: the cube or the plane?

Answer: whichever is in front

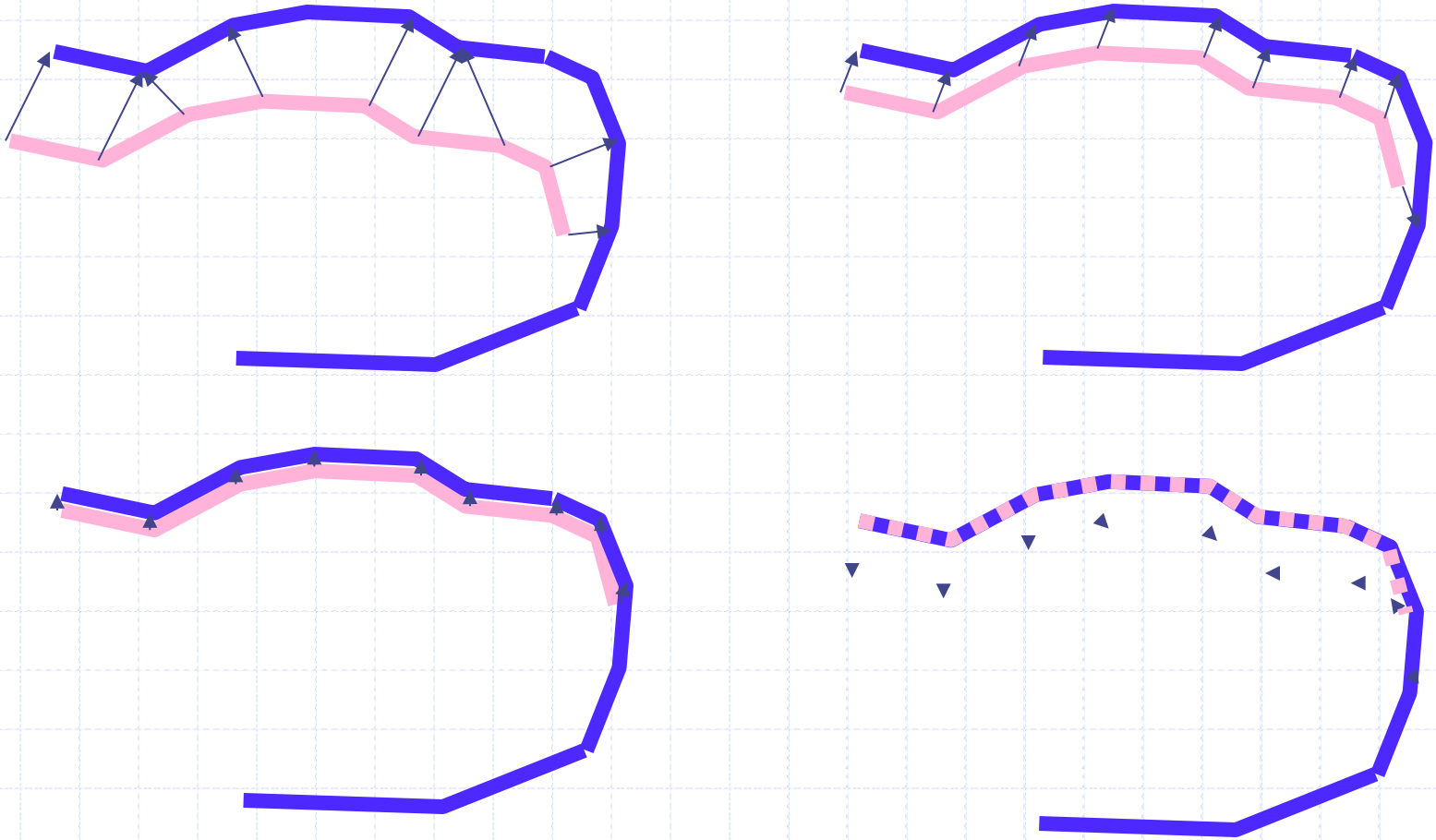
Correspondence Searching in Range Image Registration:

Range Image Registration



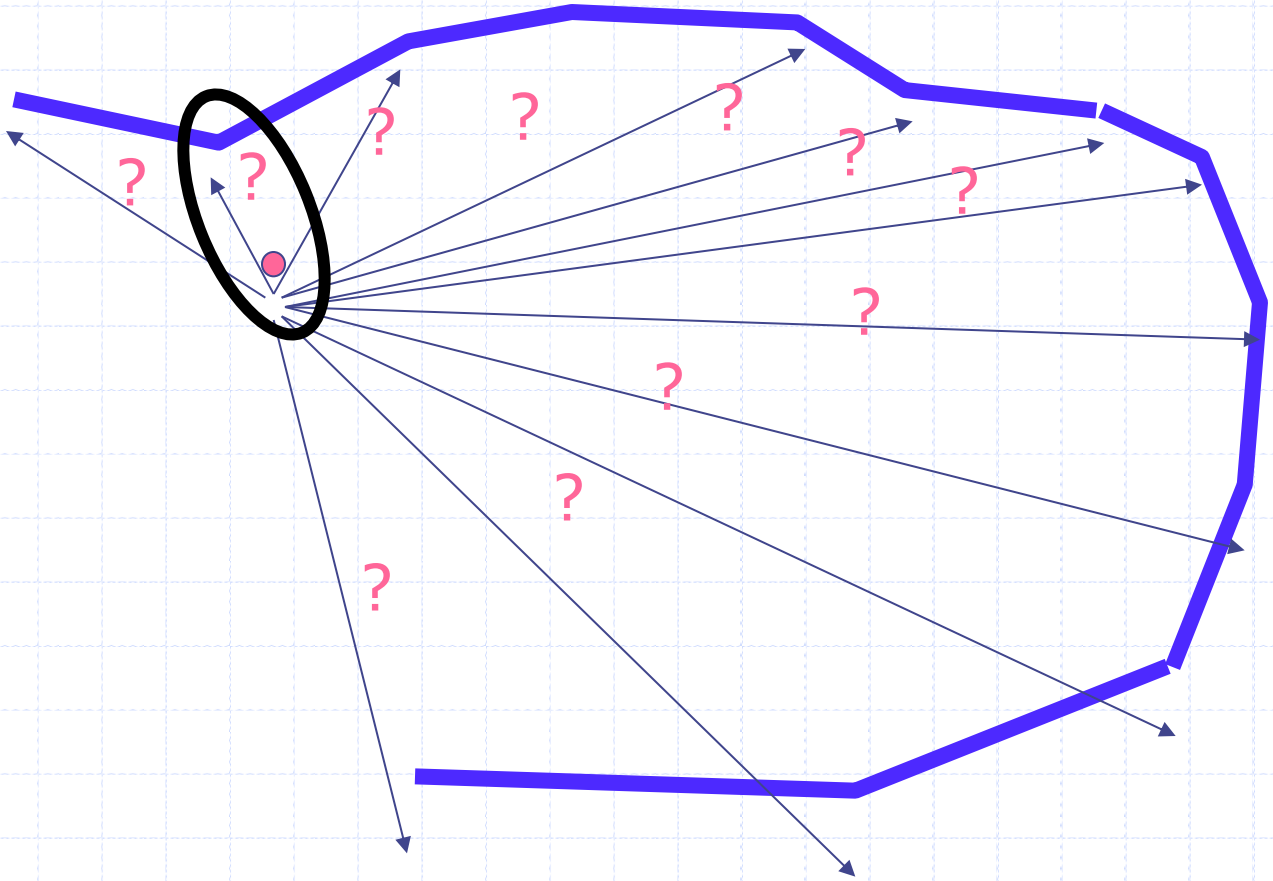
Correspondence Searching in Range Image Registration:

Range Image Registration (cont.)

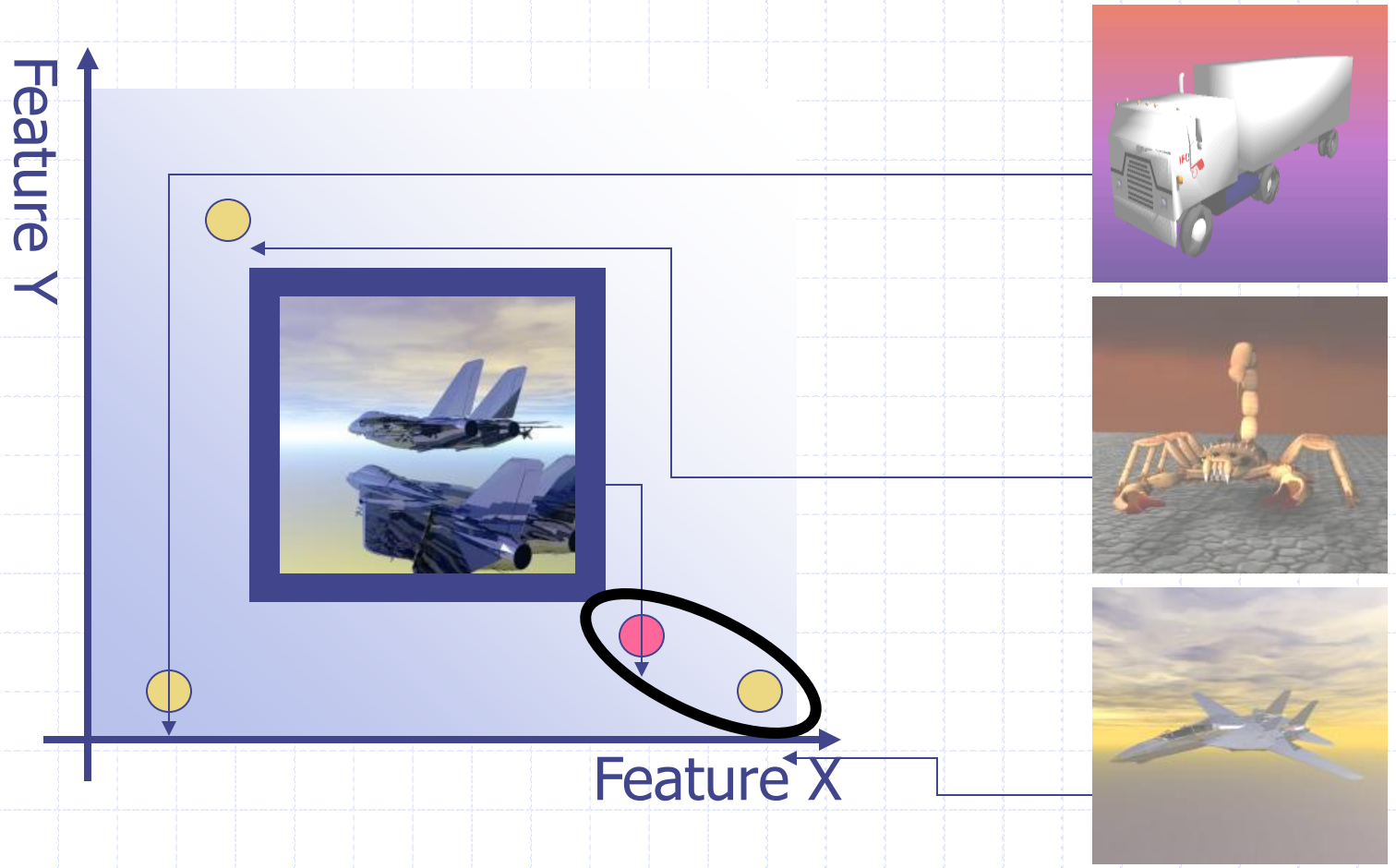


Correspondence Searching in Range Image Registration:

Correspondence Search



Nearest-Neighbor Searches in Matching



Images from http://avalon.viewpoint.com/

Why Bother?

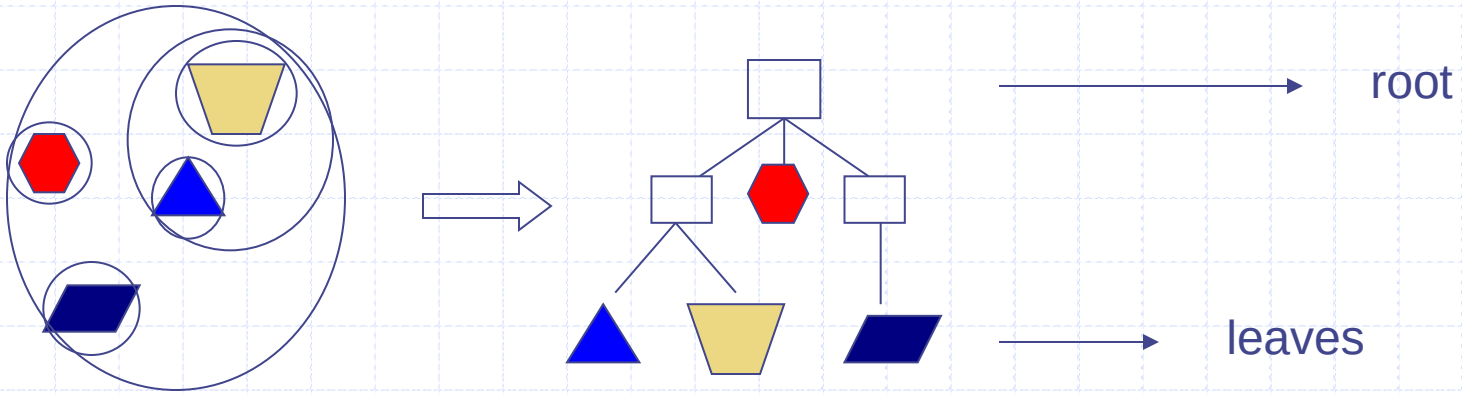
- O(N) vs. O(log N)
- Nearest-neighbor searches
  - Range Image Registration
  - High-dimensional feature-based object/image matching
- Ray-object intersections
  - Range Image Registration
  - Ray tracing
- Volumetric object representations

Options

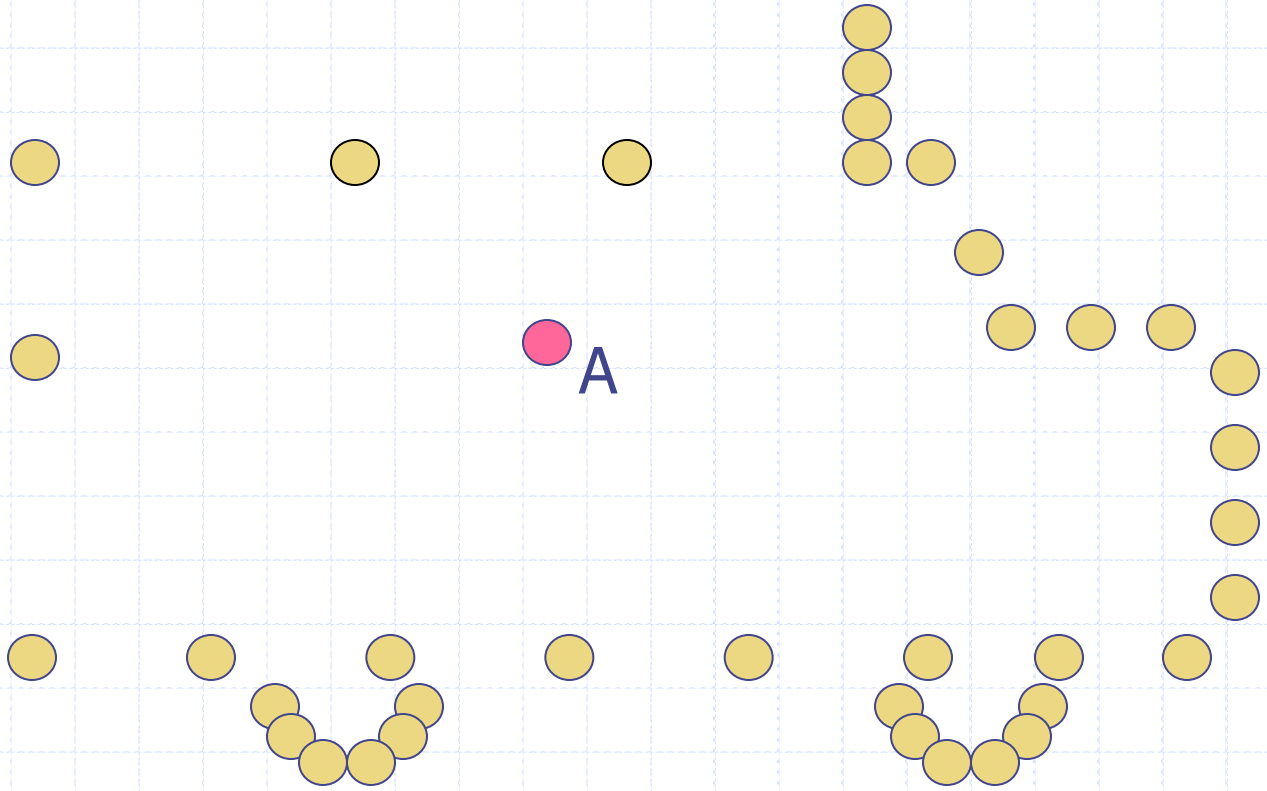
- Bottom-up approach:
  - Bounding Volume Hierarchy
    - "put objects into groups"
- Top-down approach:
  - Spatial Subdivision
    - "partition space into chunks"

Bounding Volume Hierarchies

- Starting with each individual object (e.g., polygon, point, object, etc.), build a tree bottom-up
  - Note: top-down approaches also possible
- Each node in the tree has a bounding box ("volume") that encloses the geometry in the entire subtree
- The actual data is contained in the leaf node

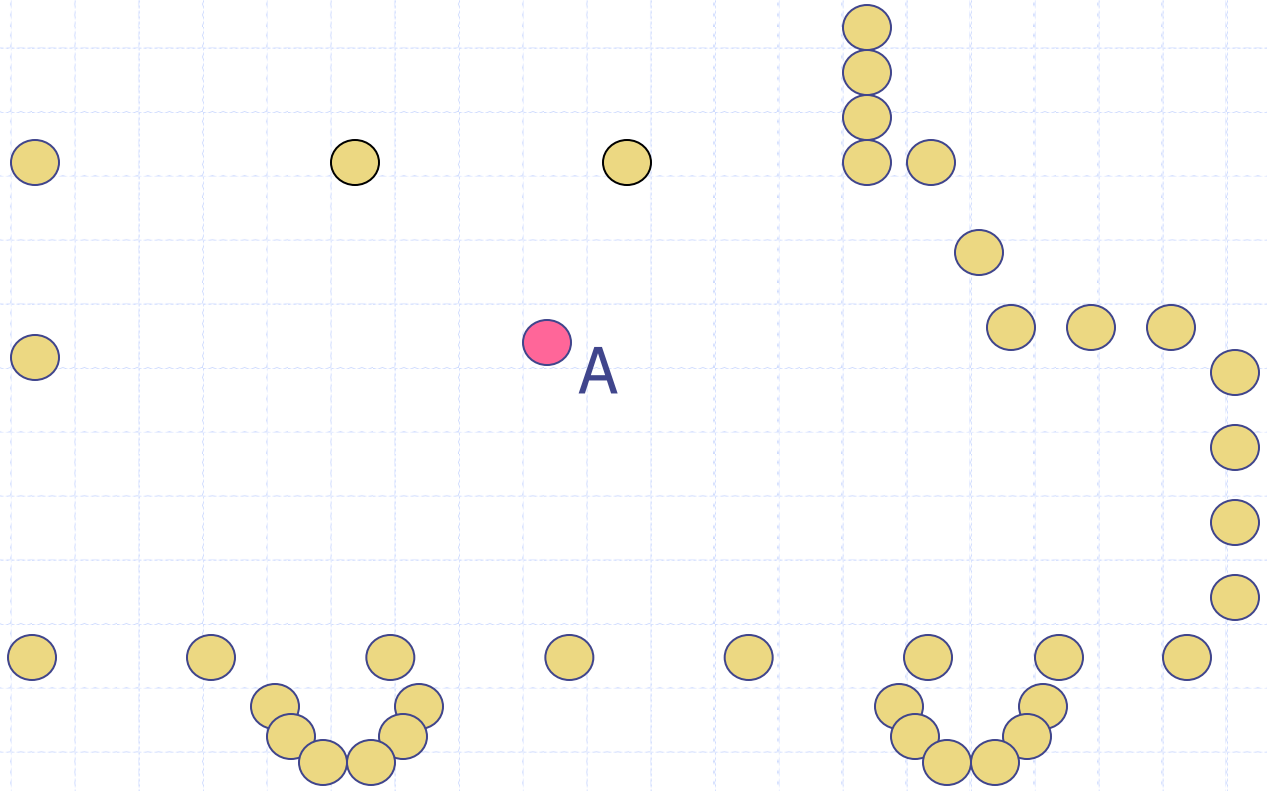


Spatial Subdivision



What point/object is closest to A?

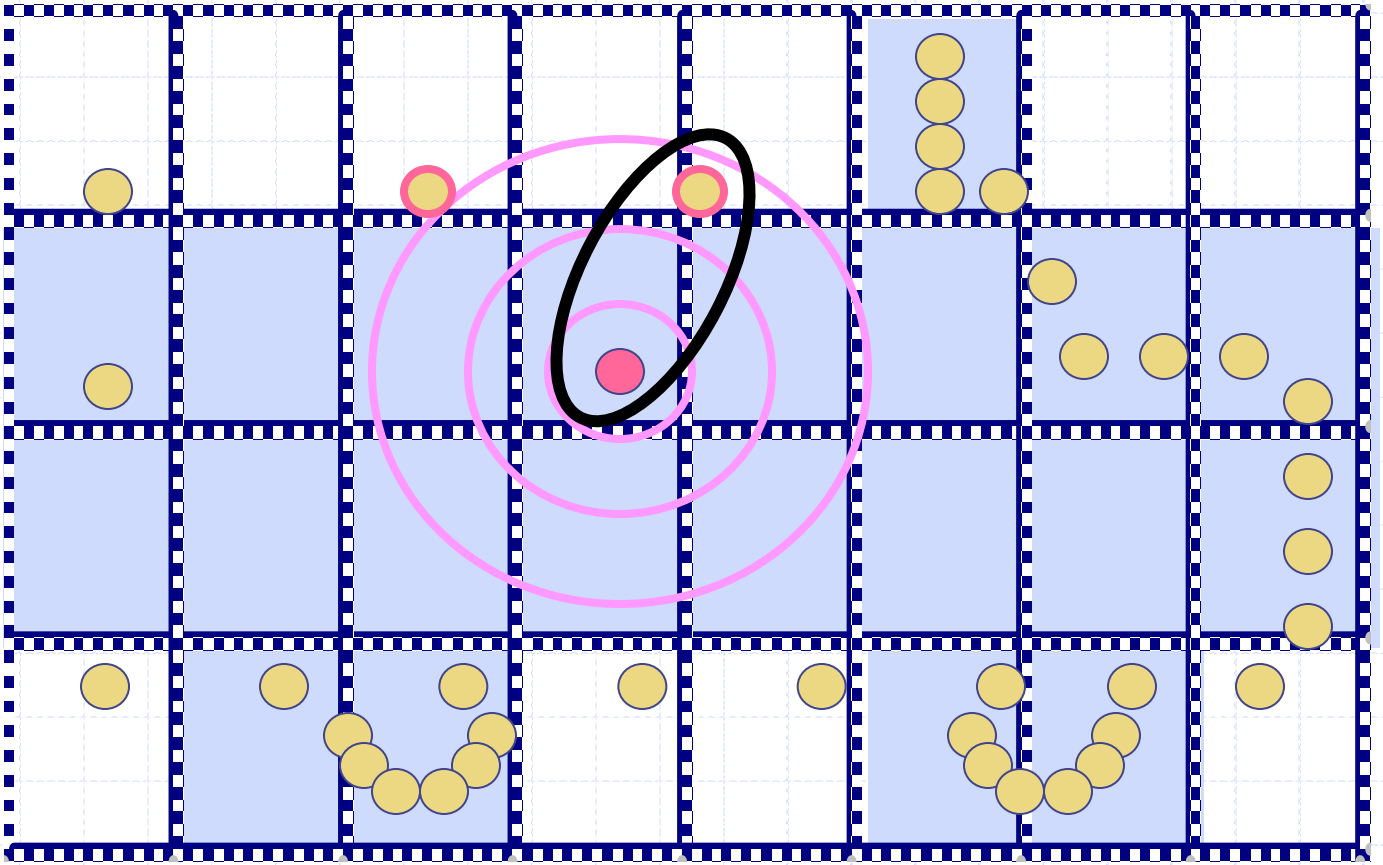
Spatial Subdivision



How can I organize the data to efficiently find points/objects near any A?

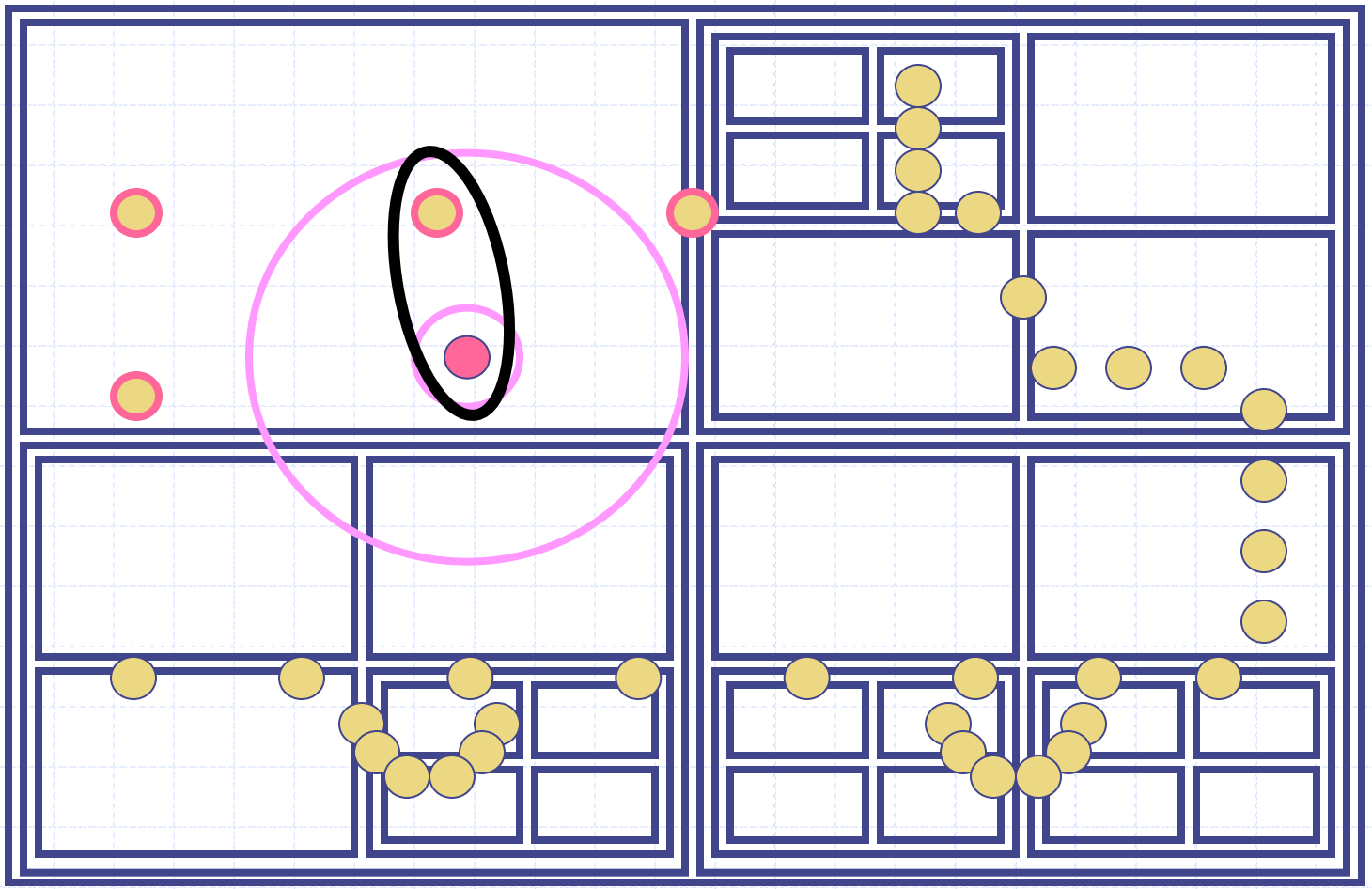
Spatial Subdivision Techniques:

Uniform Subdivision



Spatial Subdivision Techniques:

Octrees in 3D/Quadtrees in 2D



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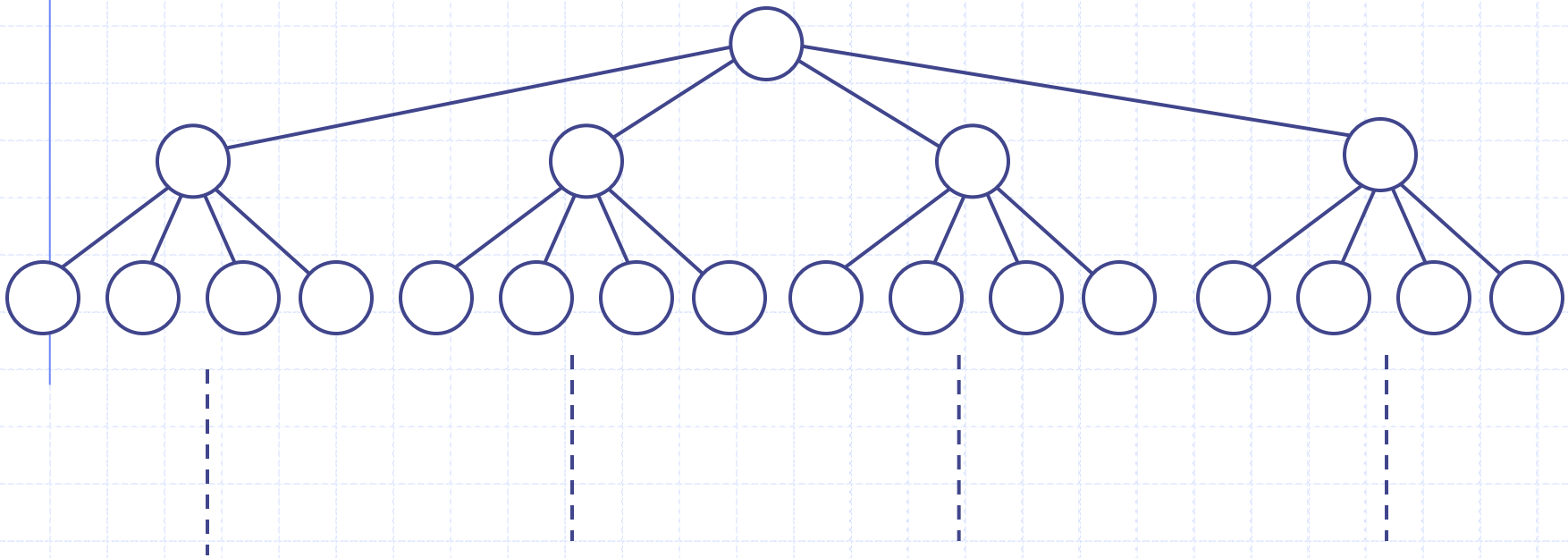
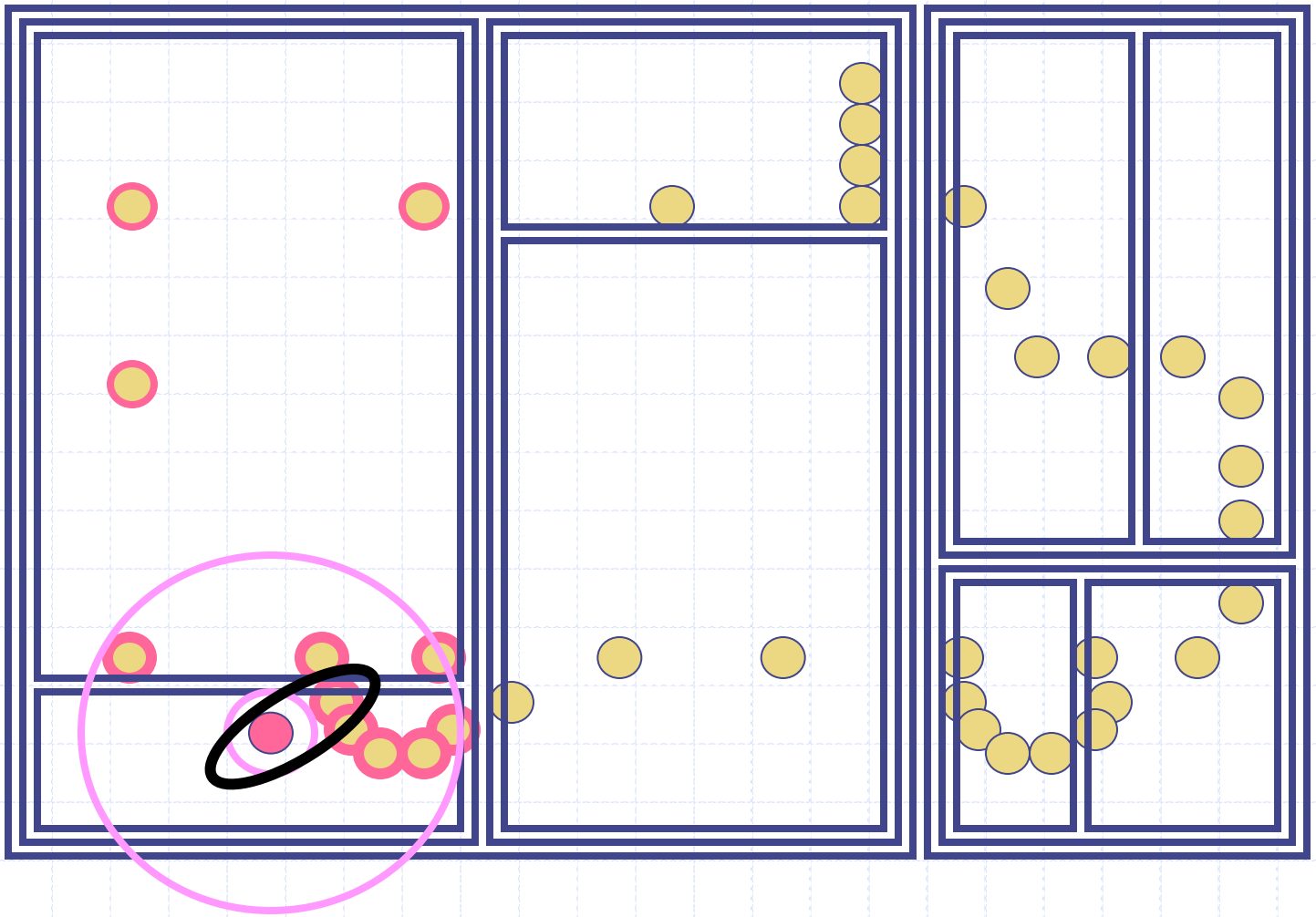


Spatial Subdivision Techniques:

k-D Trees



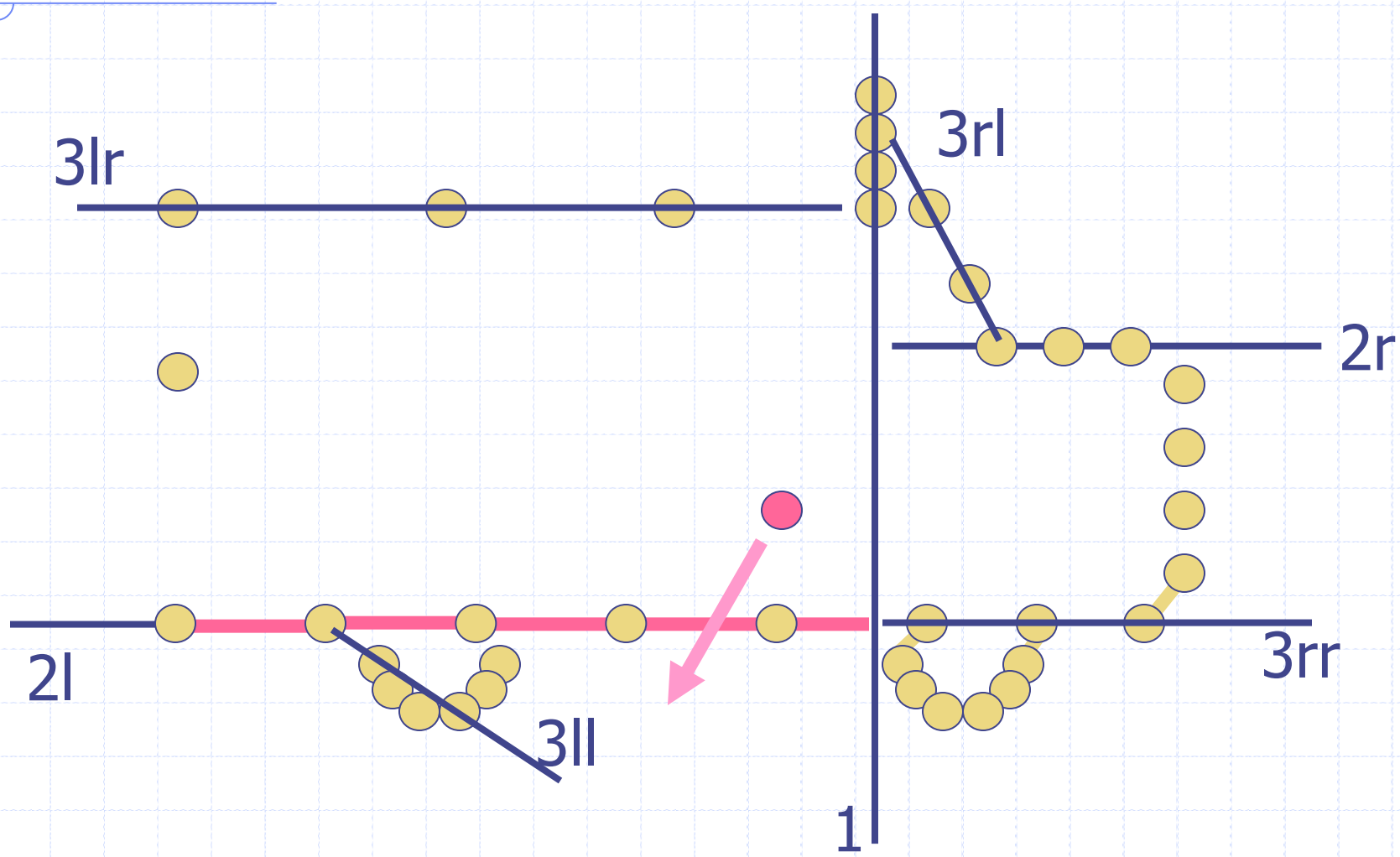
Spatial Subdivision Techniques:

Binary Space Partitioning (BSP) Trees

- A generalization:
  - Can we just split space recursively and arbitrarily?
    - Yes – the smarts are in knowing what the recursive split is but that is application dependent

Spatial Subdivision Techniques:

Binary Space Partitioning (BSP) Trees



For Further Information…

- Foley, van Dam, Feiner, Hughes. *Computer Graphics: Principles and Practice*. Addison-Wesley. 2nd Ed. 1992. *(newer edition available too)*
  - Uniform Subdivision
  - Octrees
  - BSP Trees
  - Intersection tests
- Jerome H. Friedman, Jon Louis Bentley, and Raphael Ari Finkel. "An Algorithm for Finding Best Matches in Logarithmic Expected Time." *ACM Transaction on Mathematical Software*, 3(3):209–226, September 1977.
  - k-D Trees
- Michael Abrash. *Michael Abrash's Graphics Programming Black Book.*
  - BSP Trees