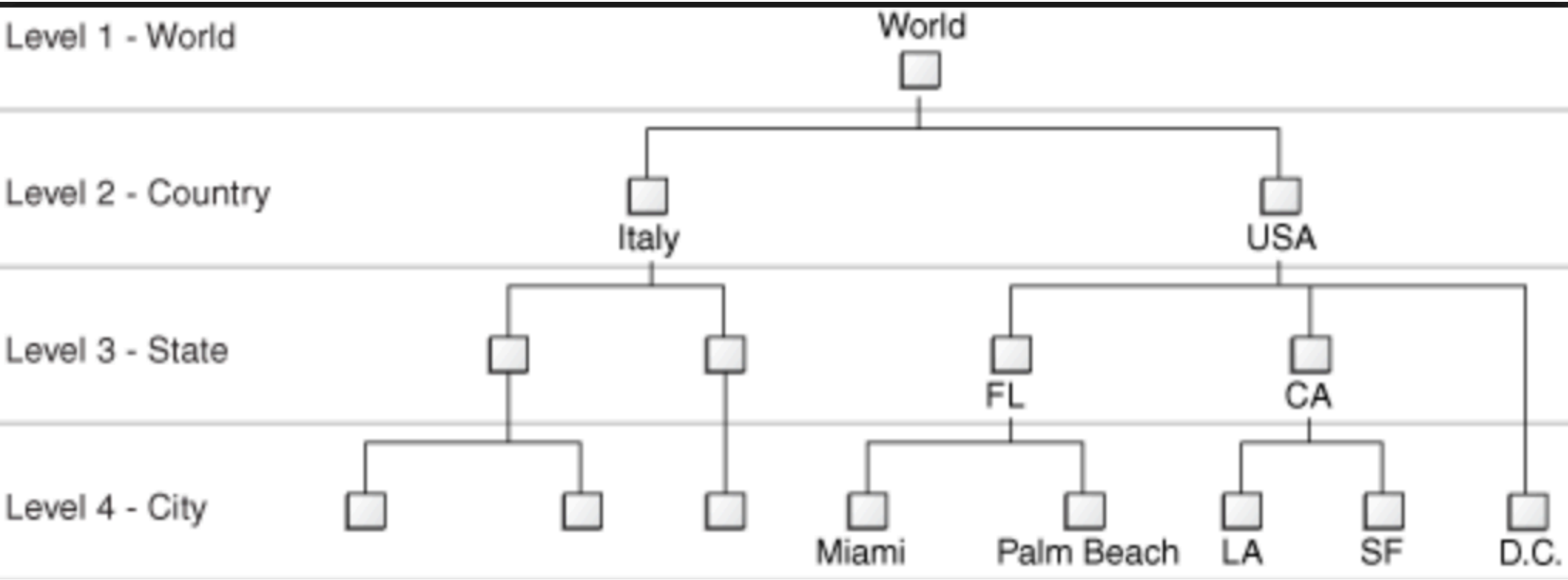
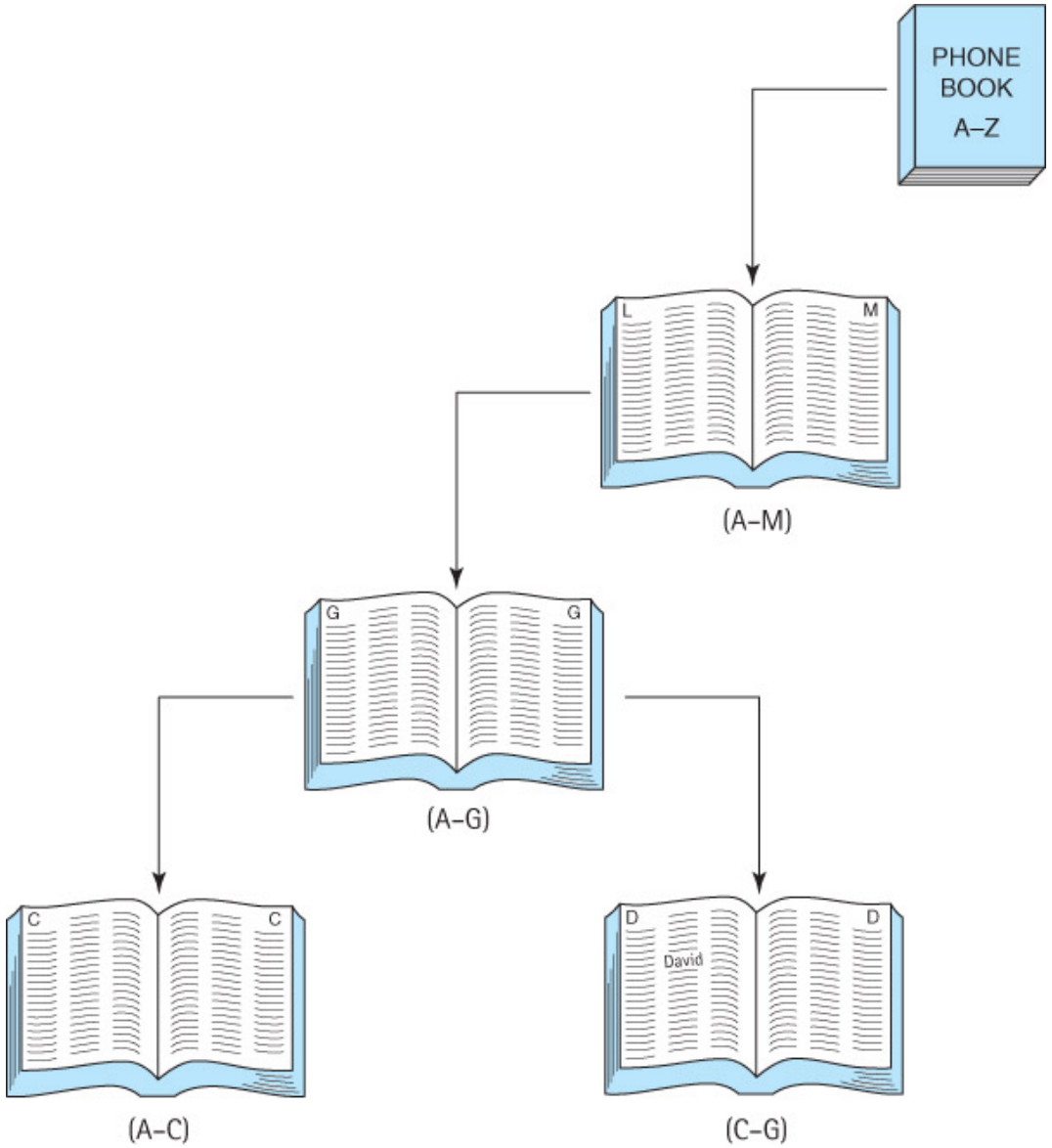
Spatial Indexing
Data Structure

Tree Hierarchy



Binary Search Idea



Search for David

1. Go to somewhere around middle
   See Miranda

2. Go to middle of the first half
   See Gilfoyle

3 Go left side again
   See Caitlyn

Searching in a phone book

- Suppose we are looking for “David” in a phone book
- We open the phone book to the middle and see that the names there begin with M
  - M is larger than (comes after) D
  - We can now limit our search to the section that contains A to M
- We turn to the middle of the first half and see that the names there begin with G
  - G is larger than D
  - We can now limit our search to the section that contains A to G
- We turn to the middle page of this section, and find that the names there begin with C
  - C is smaller than D
  - We can now limit our search to the section that contains C to G
- And so on, until we are down to the single page that contains the name “David.”

Binary Search

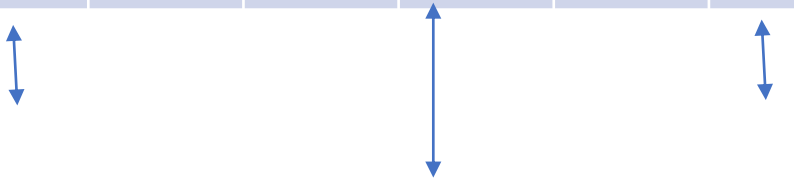
11	31	41	51	61	71	81	101	131
1	2	3	4	5	6	7	8	9

1000
500
250
125
62
31
15
7
3
1
0

Logarithm

Binary Search

11	31	41	51	61	71	81	101	131
1	2	3	4	5	6	7	8	9



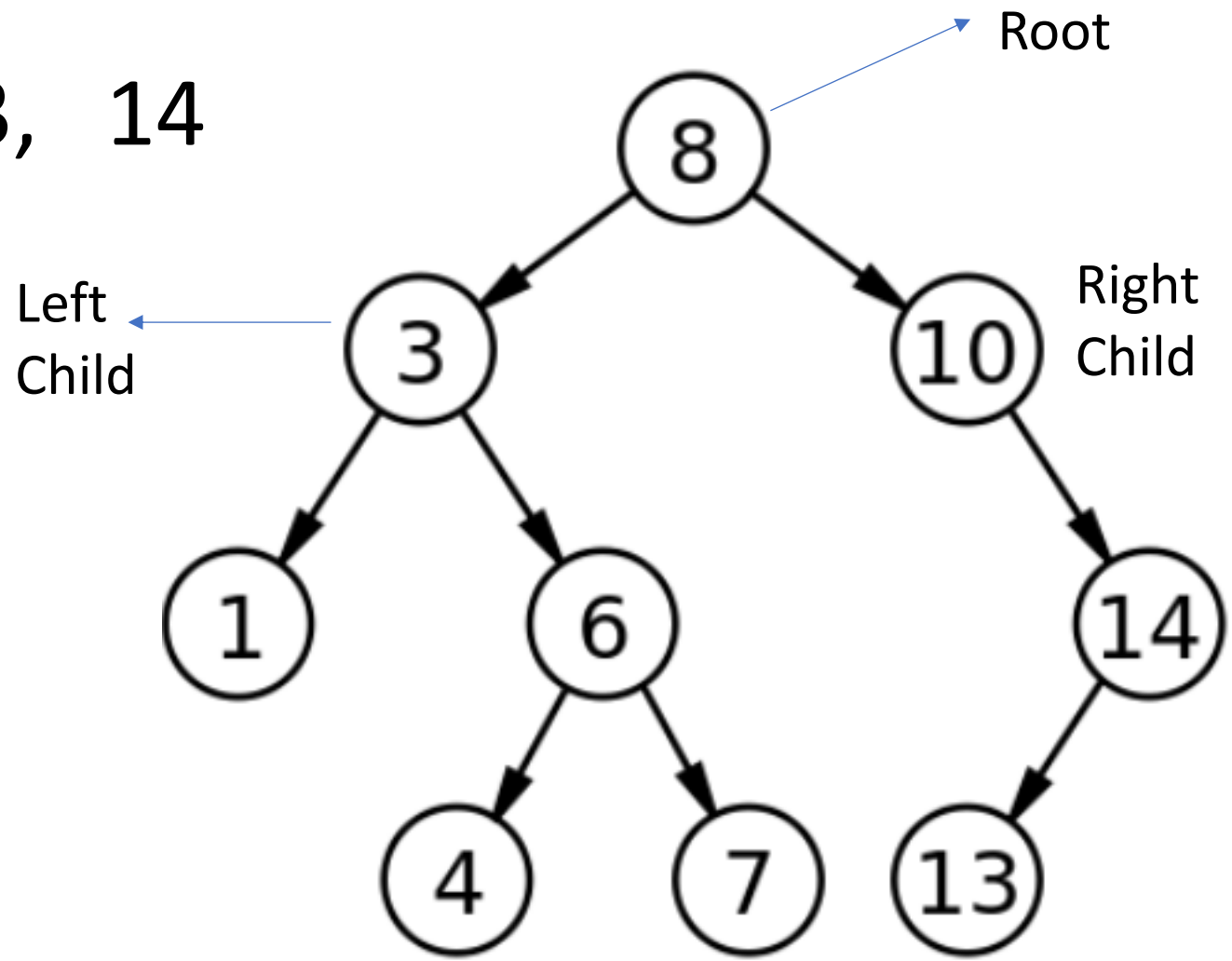
Items	Sequential Worst case	Binary Search
1K	1K	$\log_2$ (1K) = 10
1Million	1 M	$\log_2$ (1M) = 20
1 Billion	1 Billion	$\log_2$ (1 B) = 30

1000
500
250
125
62
31
15
7
3
1
0

Logarithm

Binary Tree

1, 3, 4, 6, 7, 8, 10, 13, 14



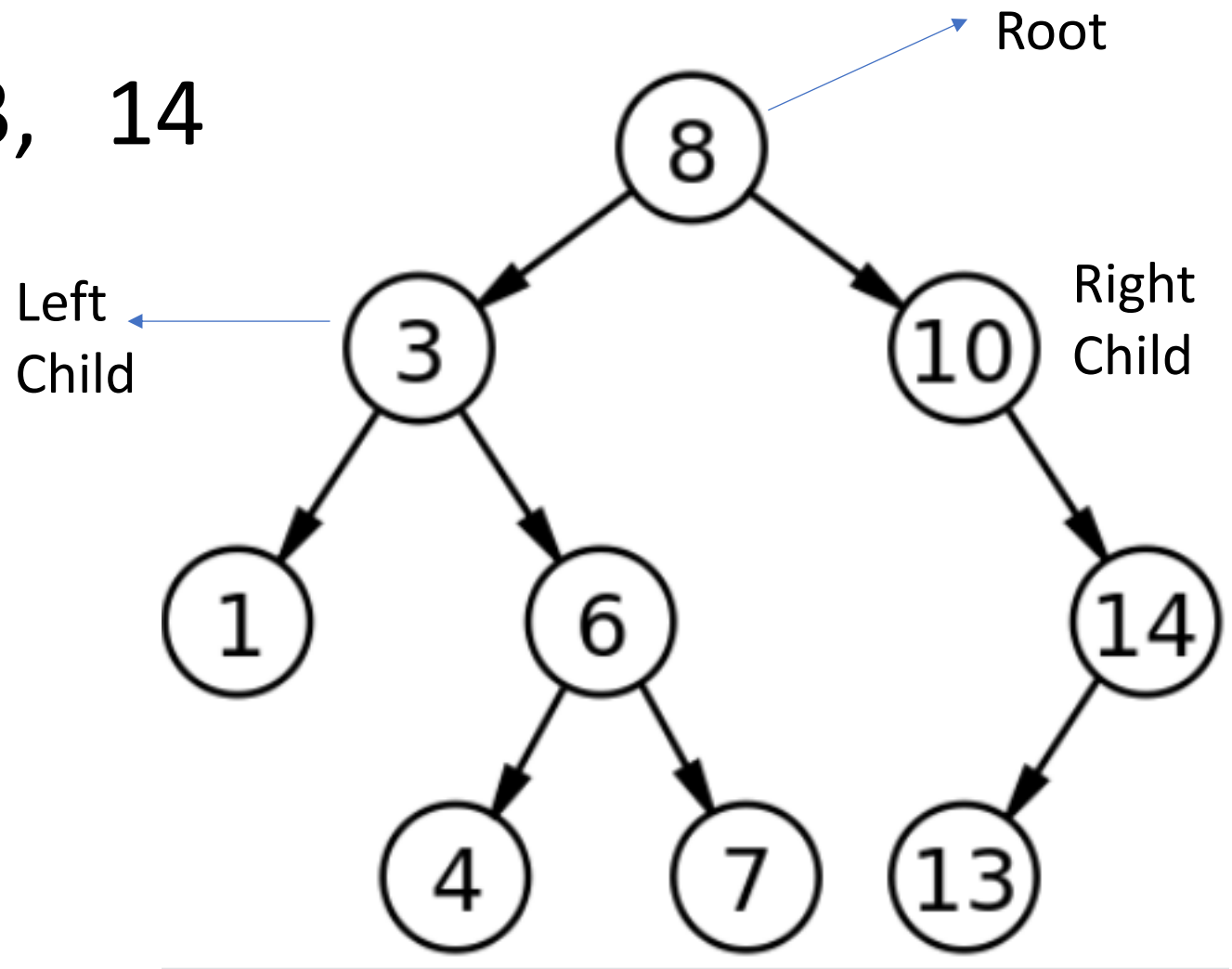
Binary **Search** Tree

1, 3, 4, 6, 7, 8, 10, 13, 14

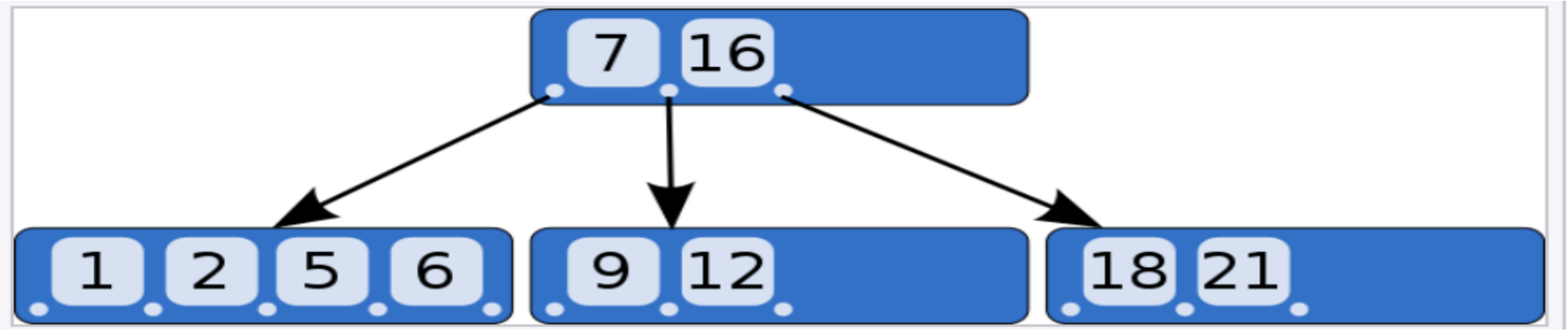
Left Child < Root

Right Child >= Root

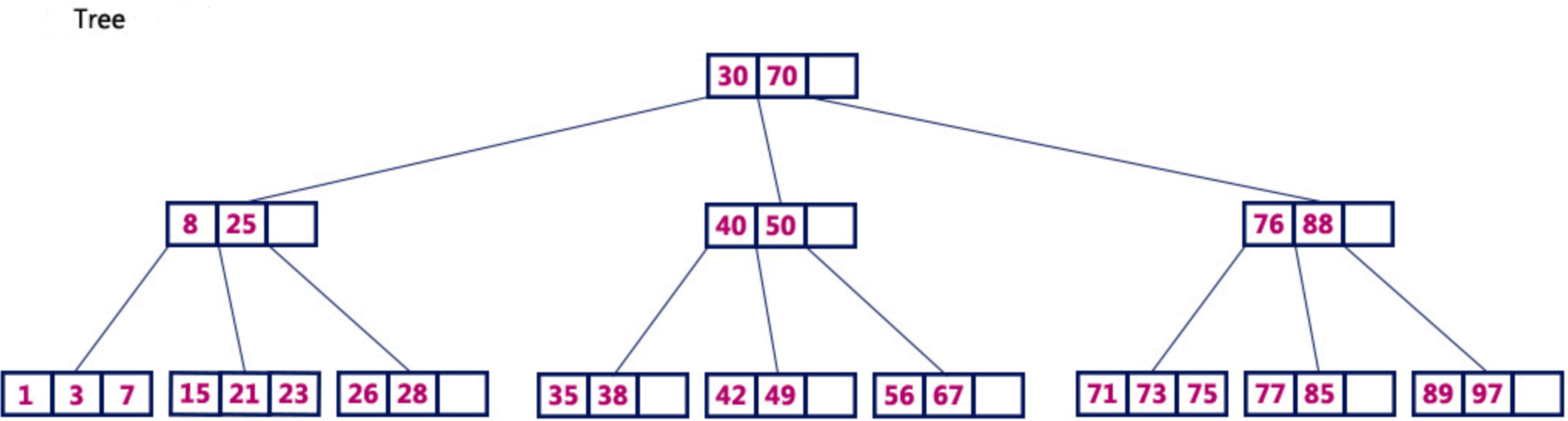
Search for 5?
Does 5 exist?



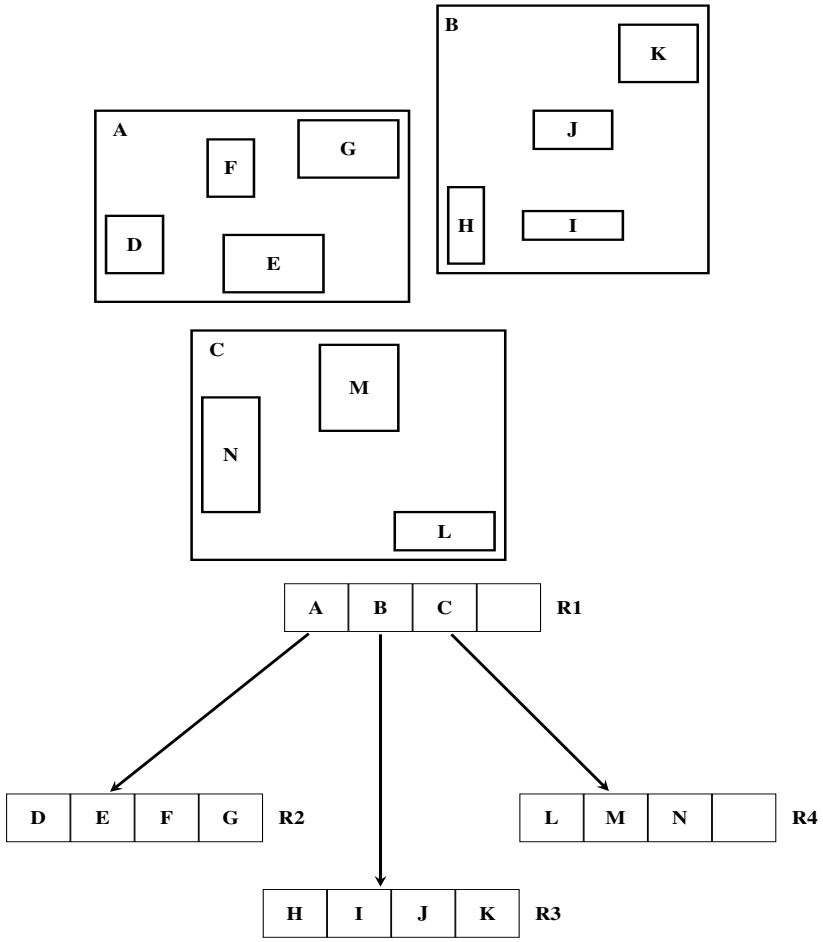
B-Tree



Pop quiz: Is this binary tree or B-Tree?



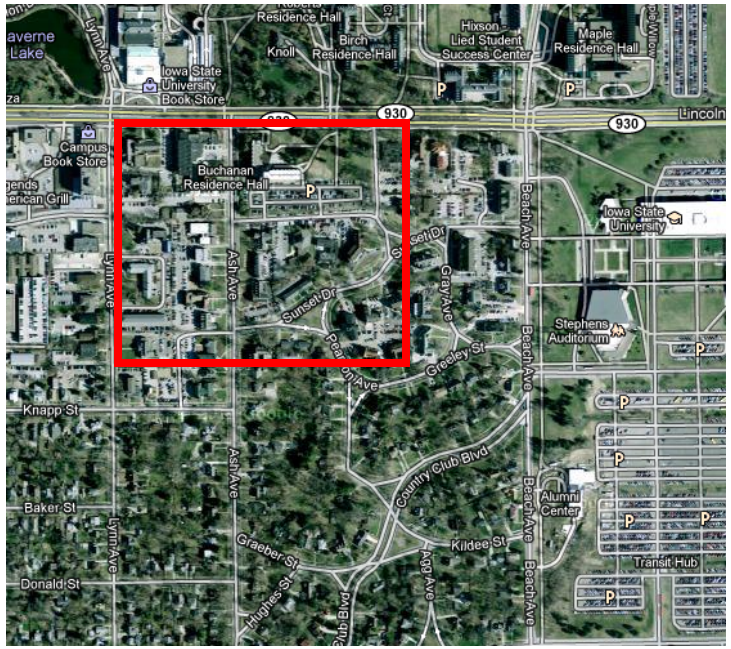
R-tree (R is rectangle)



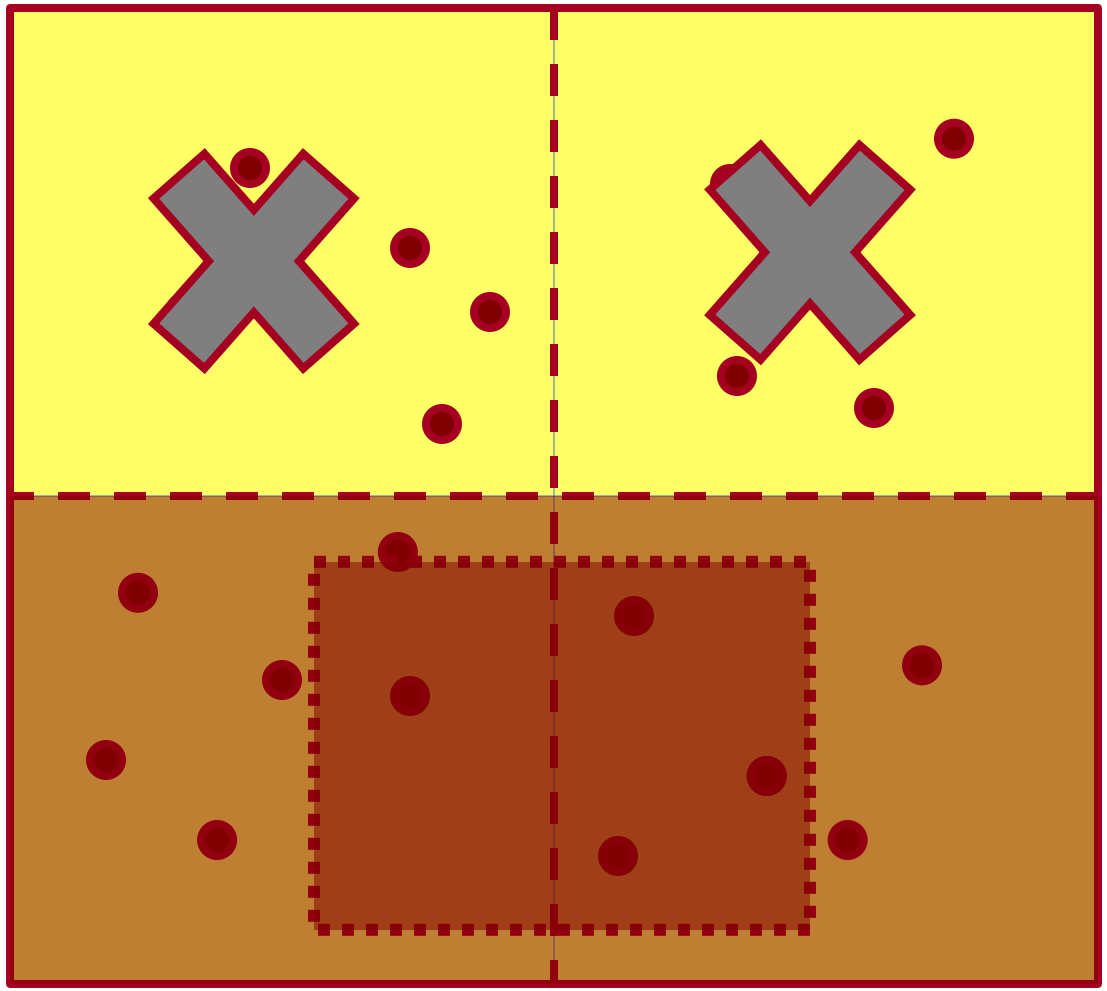
1. Similar to B-tree rectangle tree.
2. Spatial indexing
3. Fast logarithmic search

Types of Spatial Queries

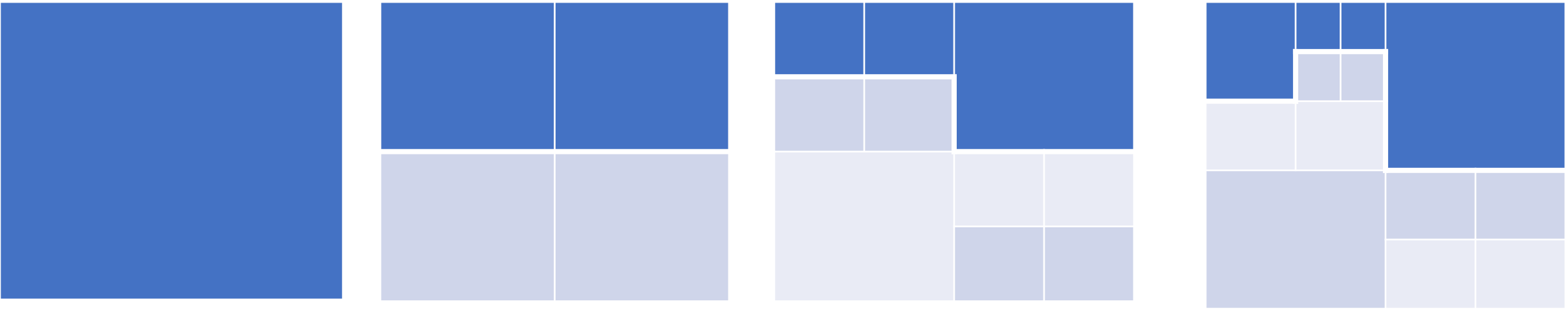
- Spatial Range Queries
  - *Find all cities within 50 miles of Ames*
  - Query has associated region (location, boundary)
  - Answer includes overlapping or contained data regions
- Nearest-Neighbor Queries
  - *Find the 10 cities nearest to Ames*
  - Results must be ordered by proximity
- Spatial Join Queries



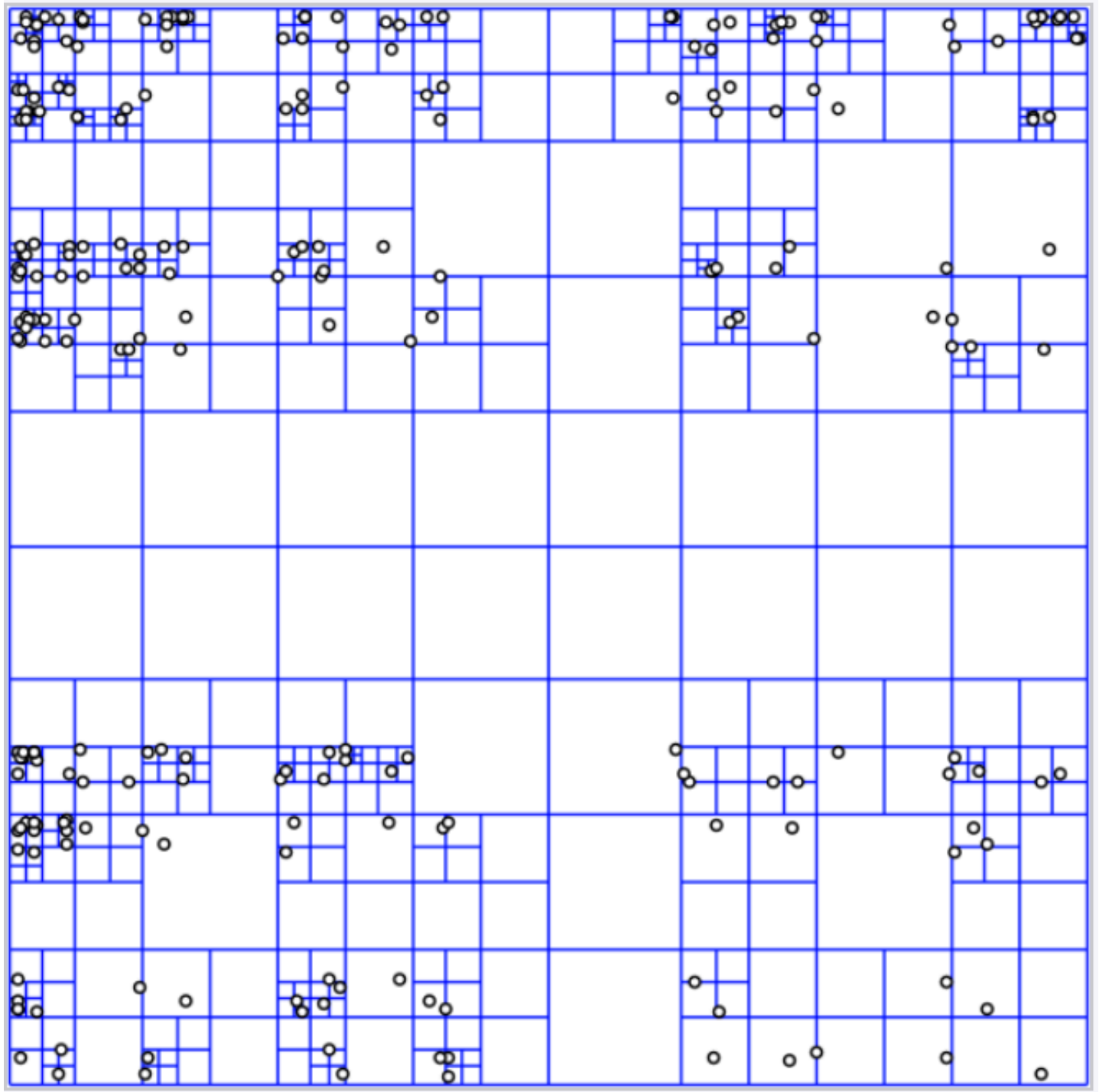
Range Query



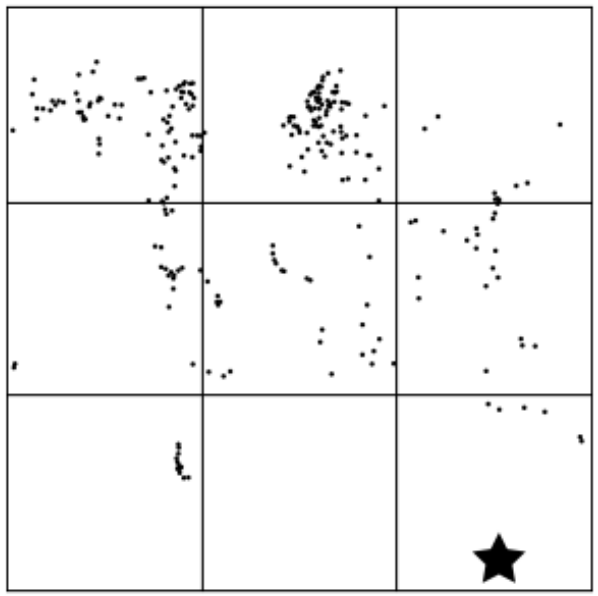
Quadtree



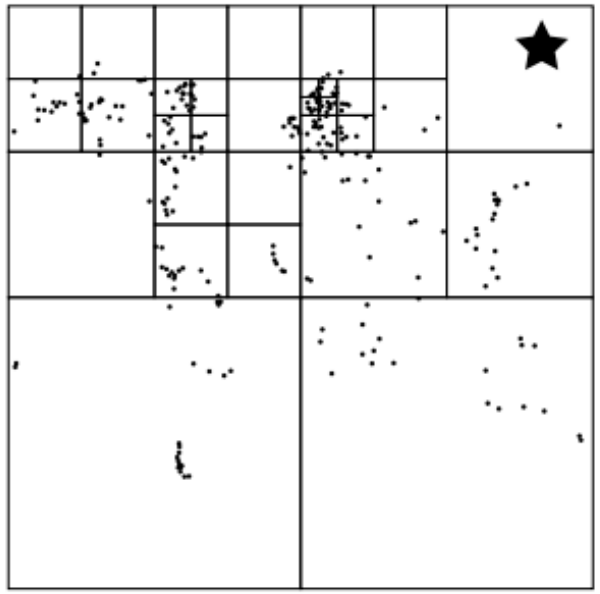
Quadtree



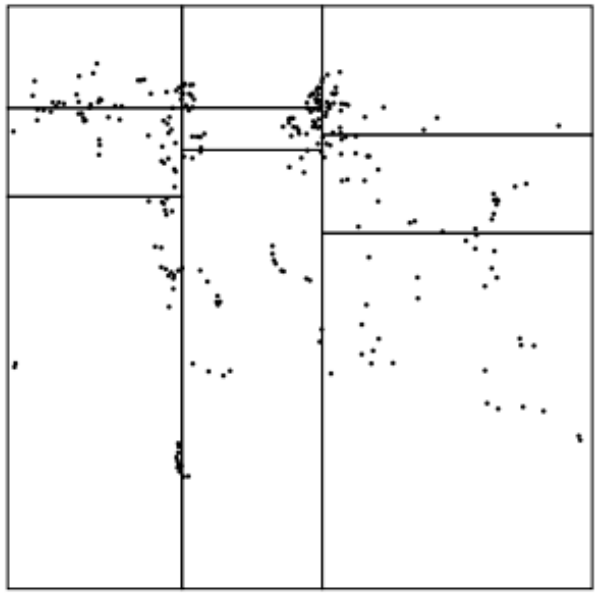
Space Partitioning



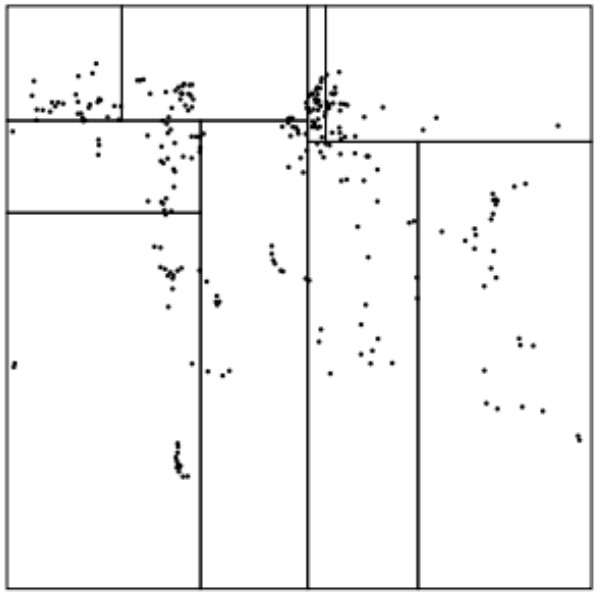
(a) Grid



(b) Quad Tree

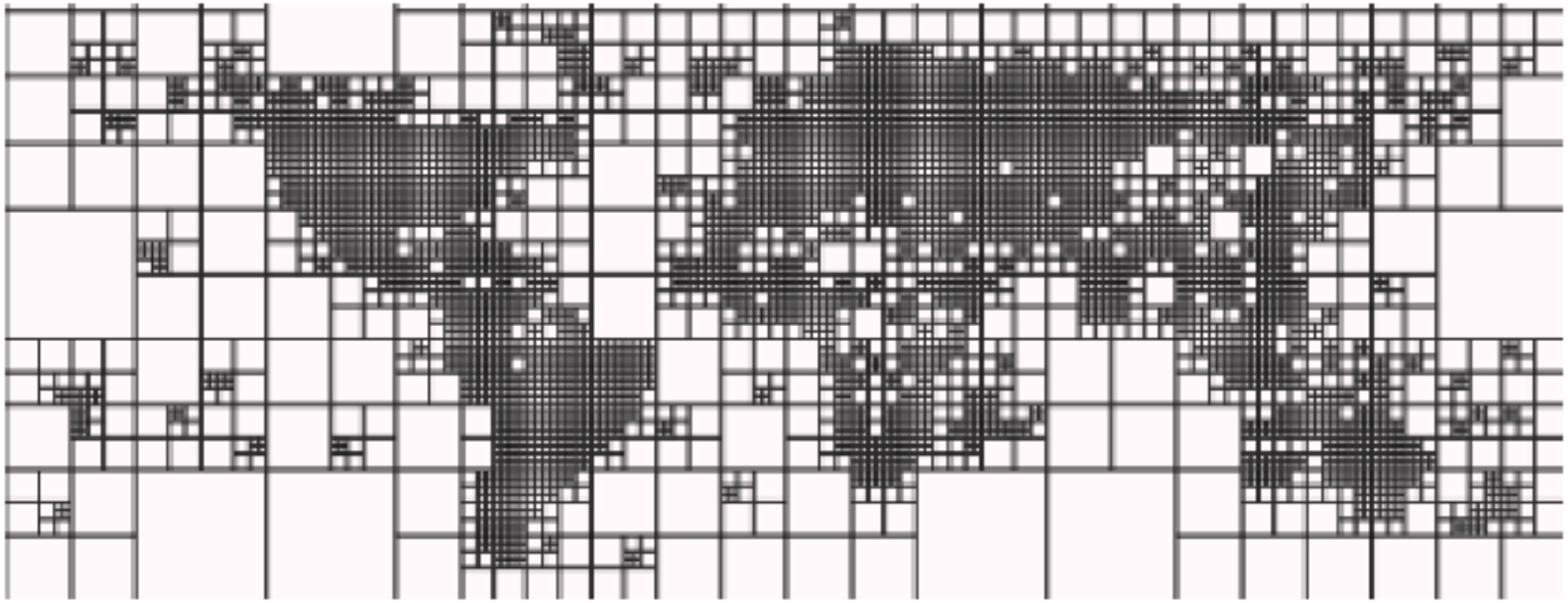


(c) STR and STR+

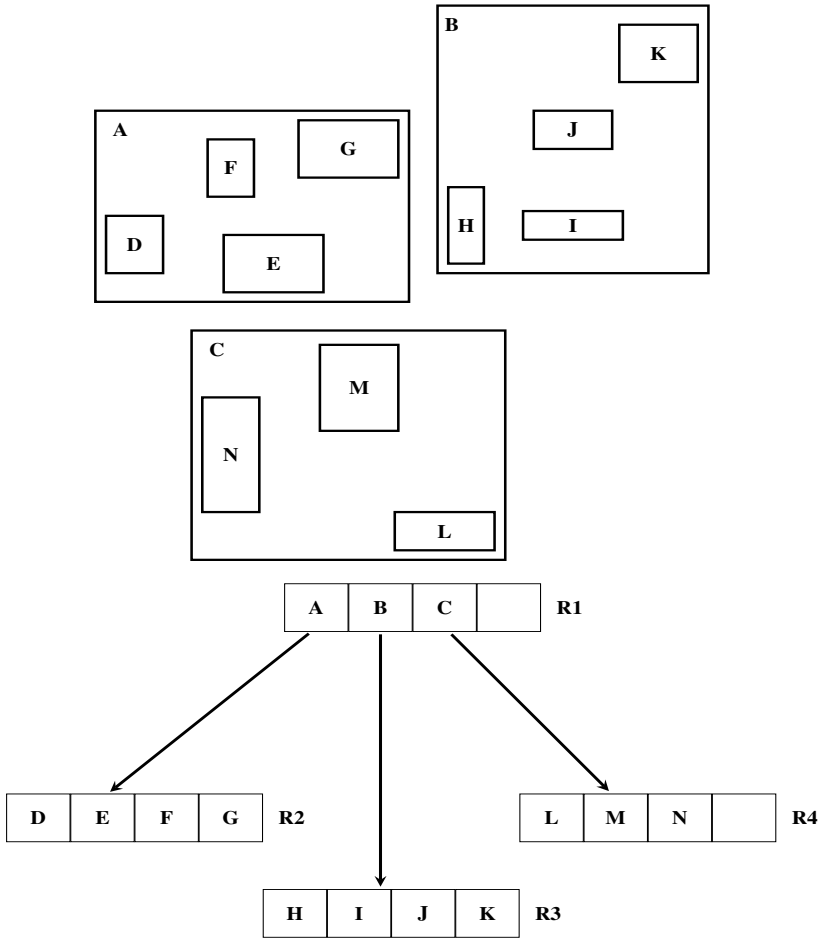


(d) K-d Tree

World Map - Quad tree (Parks)



R-tree



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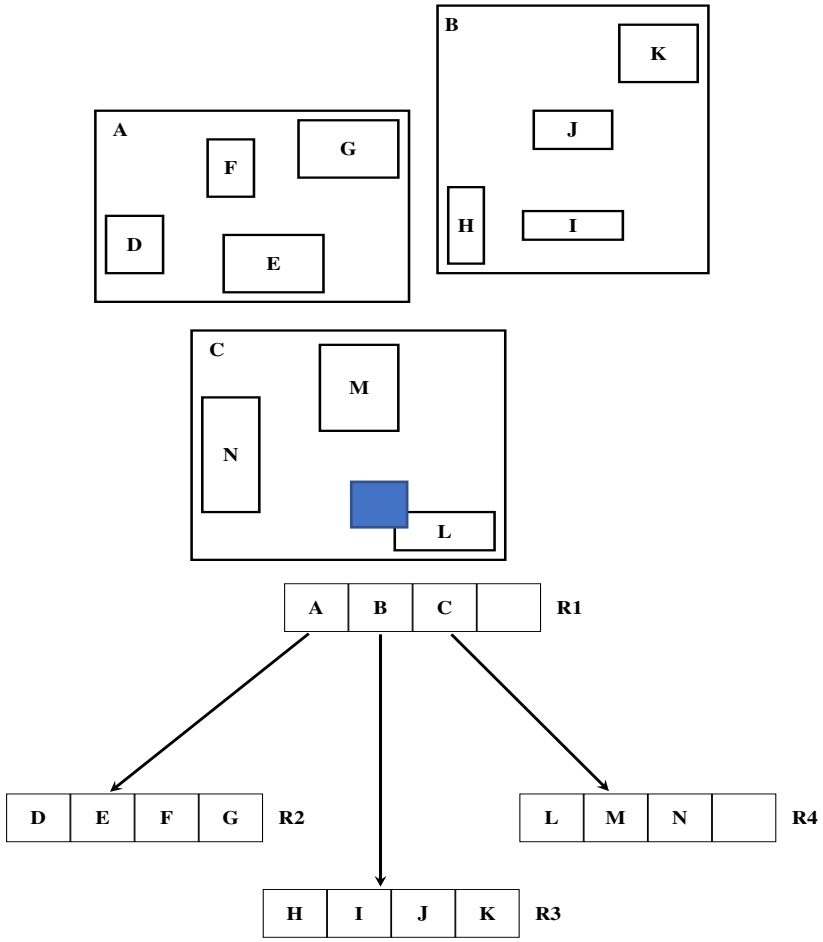
R-tree query example



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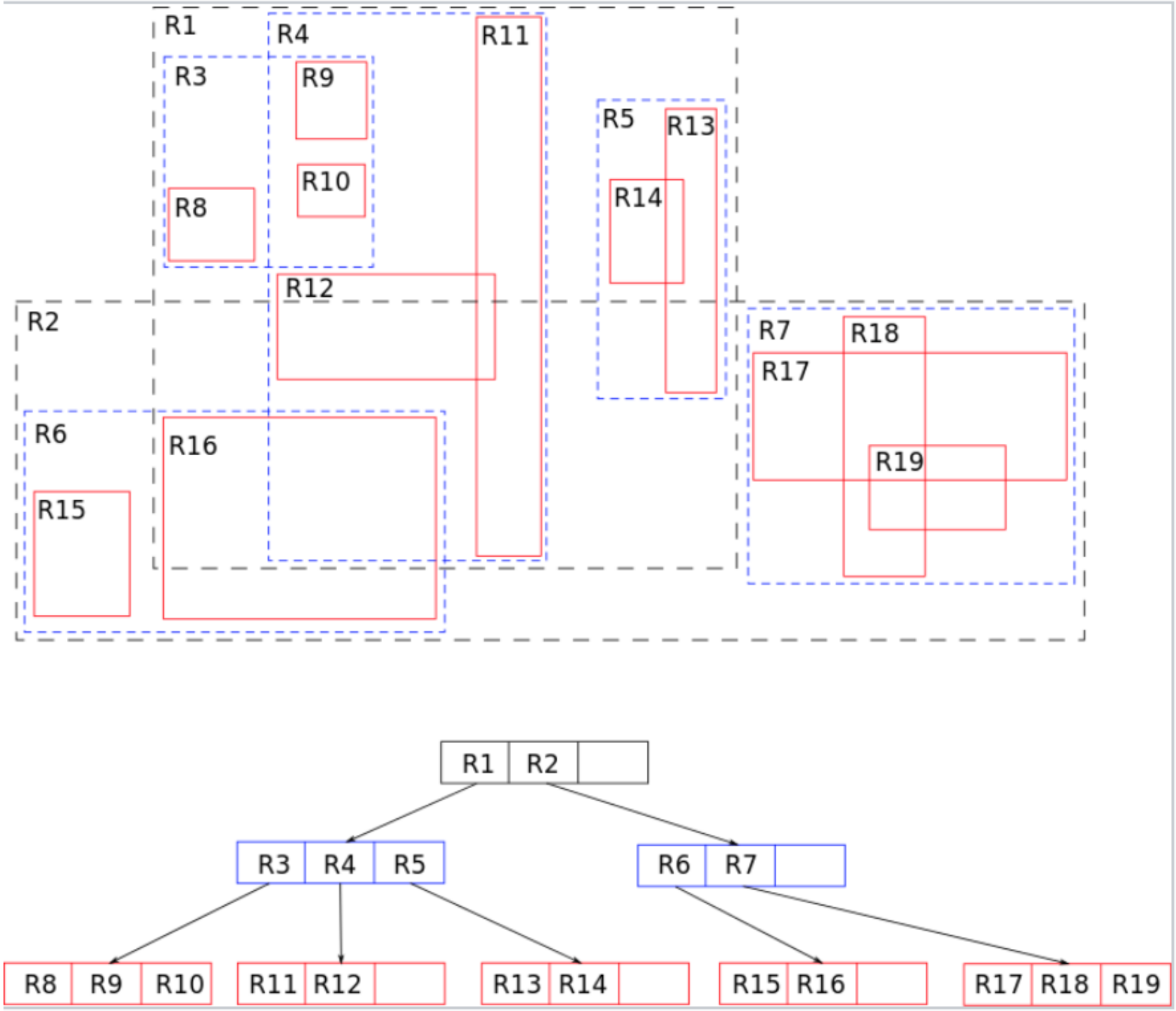
Rtree


R1
R4
R11
R3
R9
R5
R13
R10
R14
R8
R12
R2
R7
R18
R17
R6
R16
R19
R15
R1
R2
R3
R4
R5
R6
R7
R8
R9
R10
R11
R12
R13
R14
R15
R16
R17
R18
R19

Anecdote

- Chicago Insurance Company example (NU)

Range Query can be done using R-tree