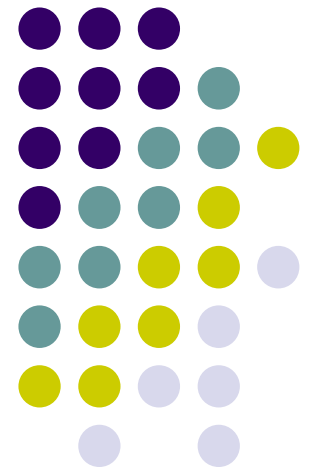
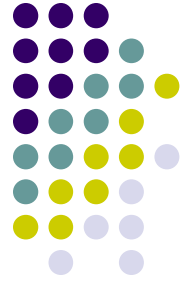


R-TREE AND SPATIAL DATABASE QUERYING

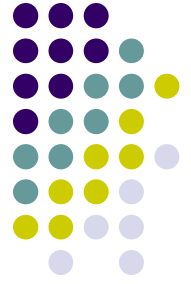
Nguyễn Quốc Thịnh - 7140027
Hồ Quang Chi Bảo - 7140219





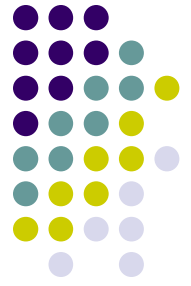
Contents

- Spatial problems in real word
- Indexing single-dimension data
- Indexing spatial data
- Summary
- References
- Q&A



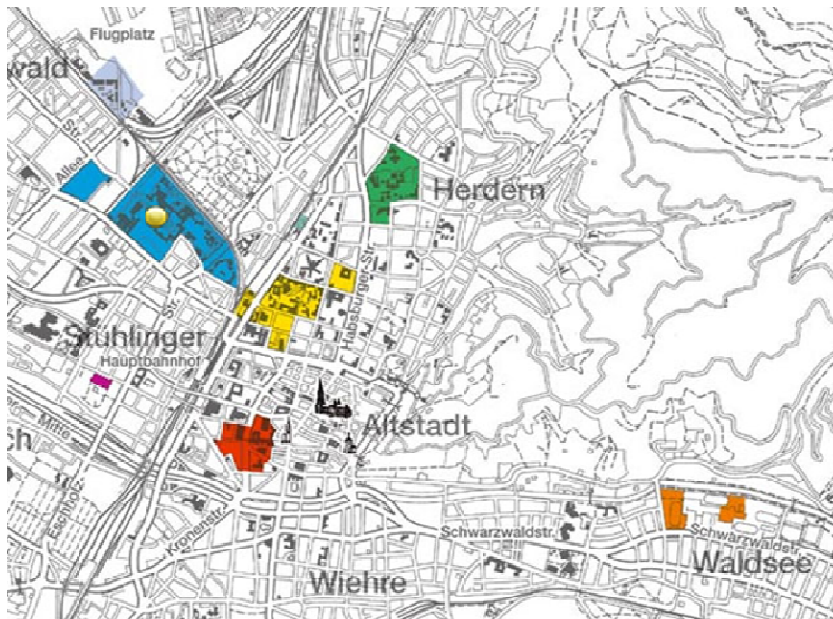
Outline

- Spatial problems in real word
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- Indexing spatial data
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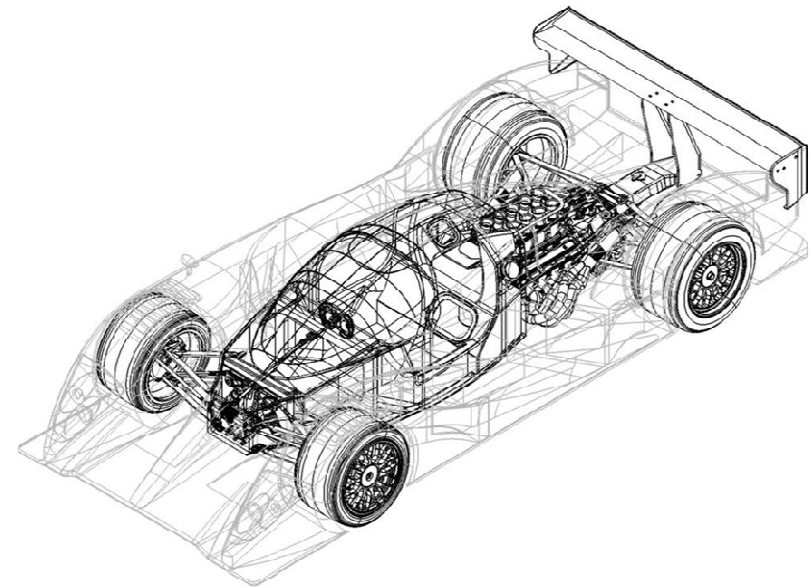


Spatial data in real word

GIS (Geographic Information System)



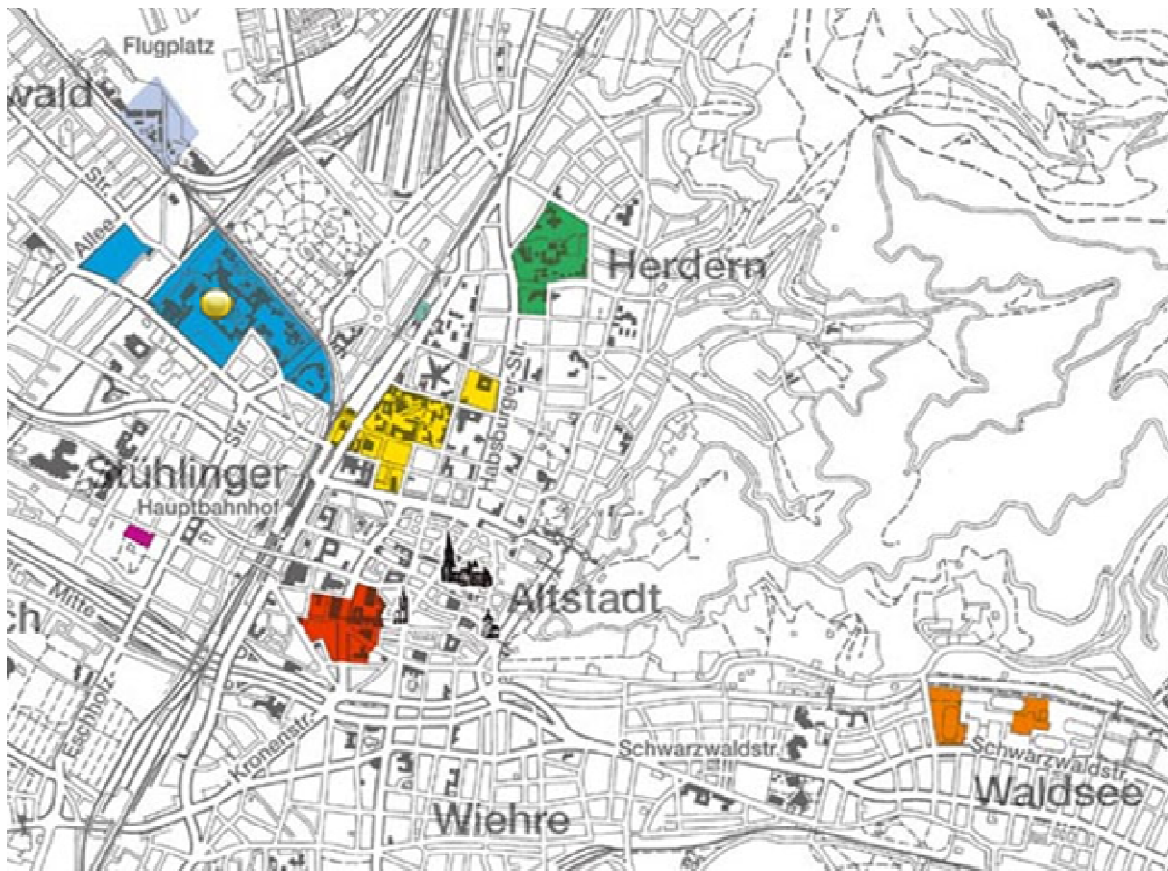
CAD (Computer Aided Design)



© Epsilon-Euskadi

Simple problem

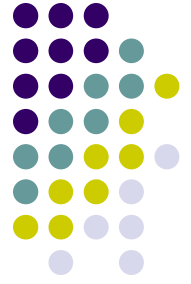
Find your university in your city





How to...

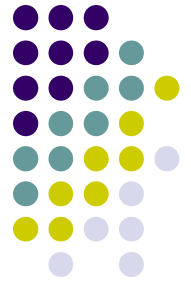
- Store spatial object into database?
 - Points, lines, surface,...
- Retrieve effectively a spatial object to answer a query quickly?
 - require a data structure to index new data objects.
- Review single-dimensional data indexing



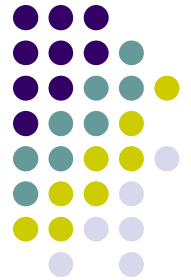
Outline

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Indexing single-dimension data

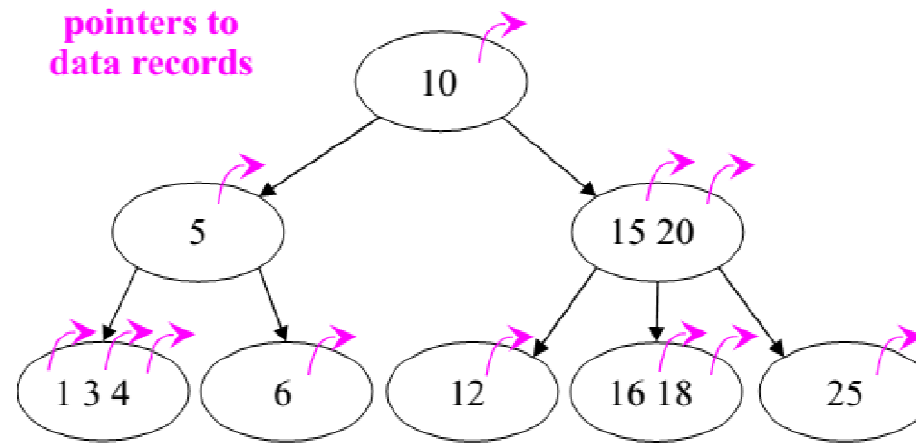


- Single dimension data:
 - integers, characters, strings, ...
- Indexing data structure:
 - B-Tree
 - B⁺-Tree

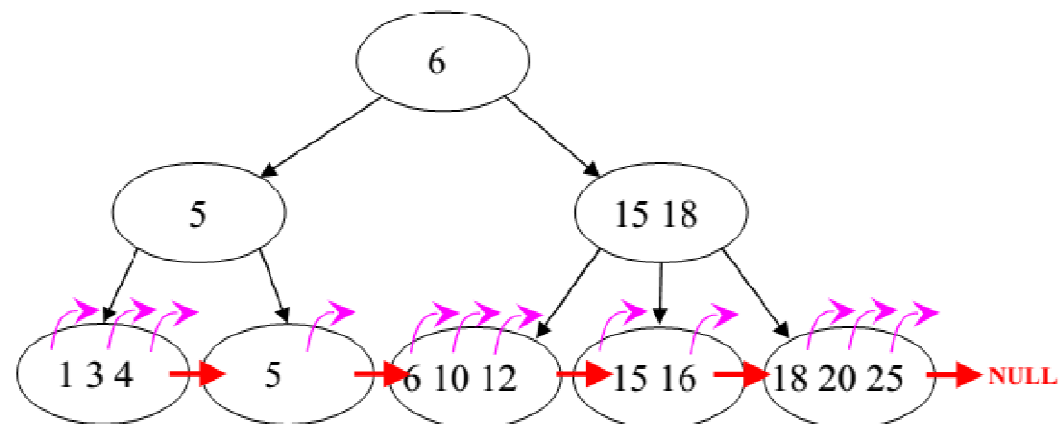


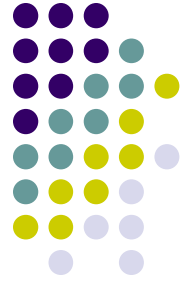
B-Tree vs. B⁺-Tree

B-Tree



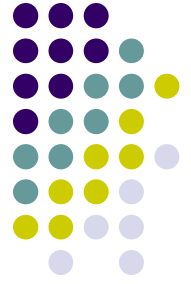
B⁺-Tree





Outline

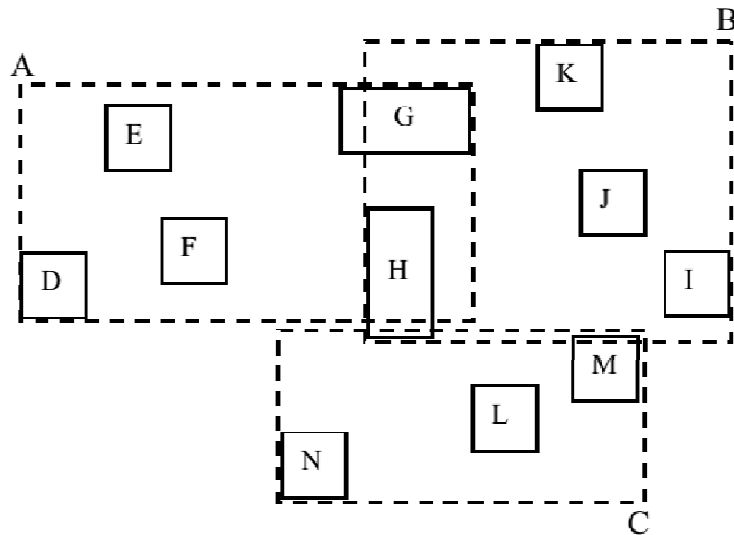
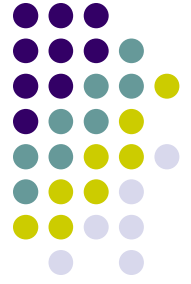
- Spatial problems in real word
- Indexing single-dimension data
- **Indexing spatial data**
- Summary
- References
- Q&A



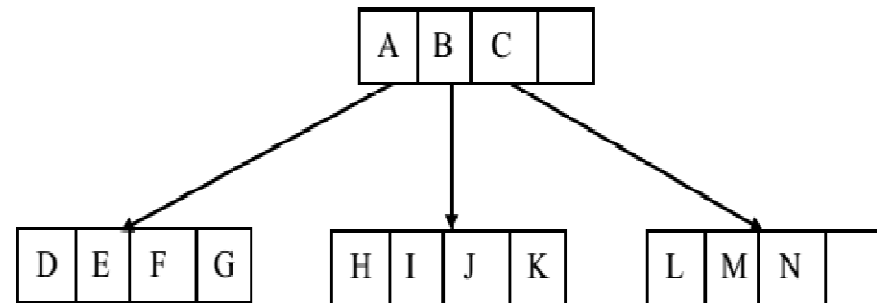
Indexing spatial data

- Multi-dimension data:
 - Spatial data
- Indexing data structure: R-Tree
- Proposed by Antonin Guttman in 1984

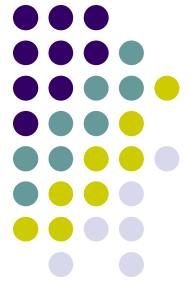
R-Tree Example



MBRs



R-Tree



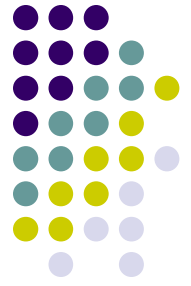
R-Tree

- Hierarchical data structures based on B⁺-Tree
- **M**inimum **B**ounding n-dimensional **R**ectangle (MBR)
- Leaf node entry form (*mbr, object-id*)
- Internal node entry form (*mbr, child-pointer*)



R-Tree characteristics

- Each node (**unless it is root node**): store from **m** to **M** entries
 - M: maximum number of entries
 - m: minimum number of entries
 - $m \leq M/2$
- Minimum allowed number of entries in root node is 2 (**unless it is a leaf**)
- All leaf nodes are at the **same level**

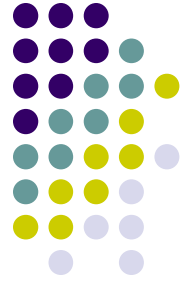


R-Tree Height

- Maximum height [1]

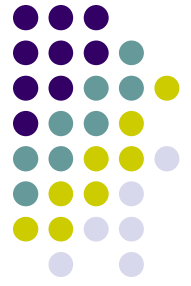
$$h_{\max} = \lceil \log_m N \rceil - 1$$

- m : minimum allowed of entries
- N : number of **data rectangles**

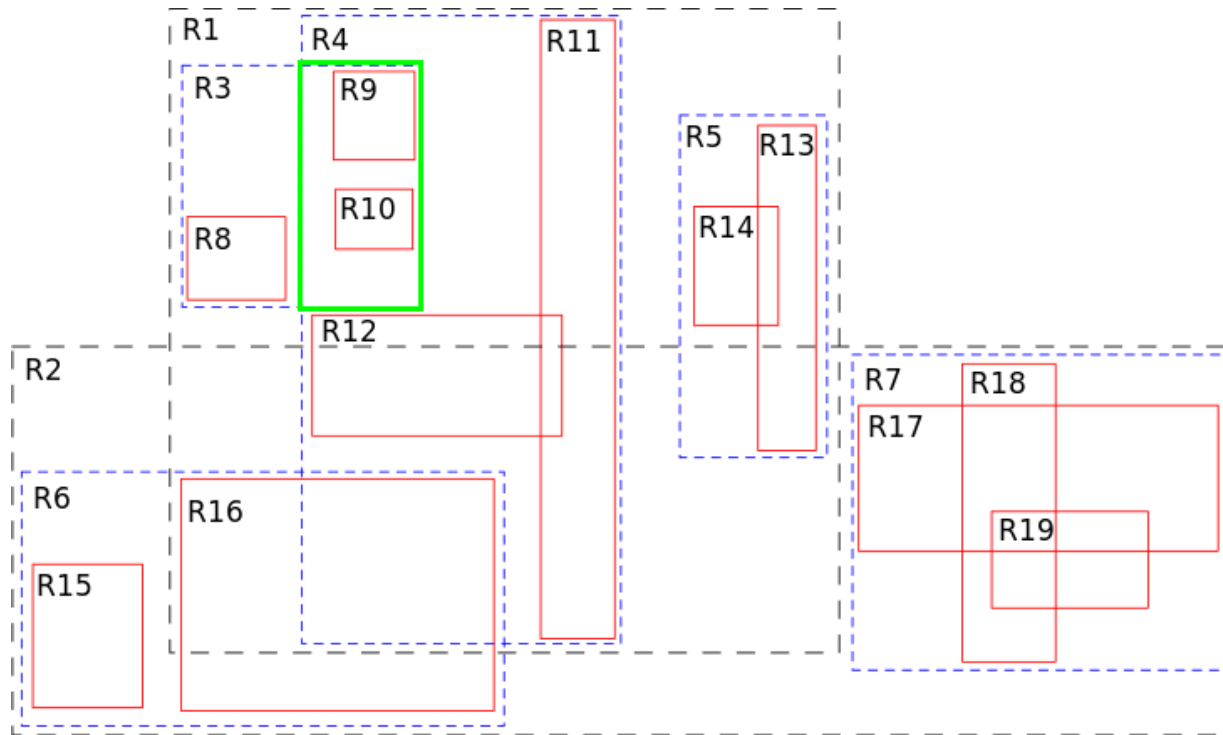


R-Tree Search

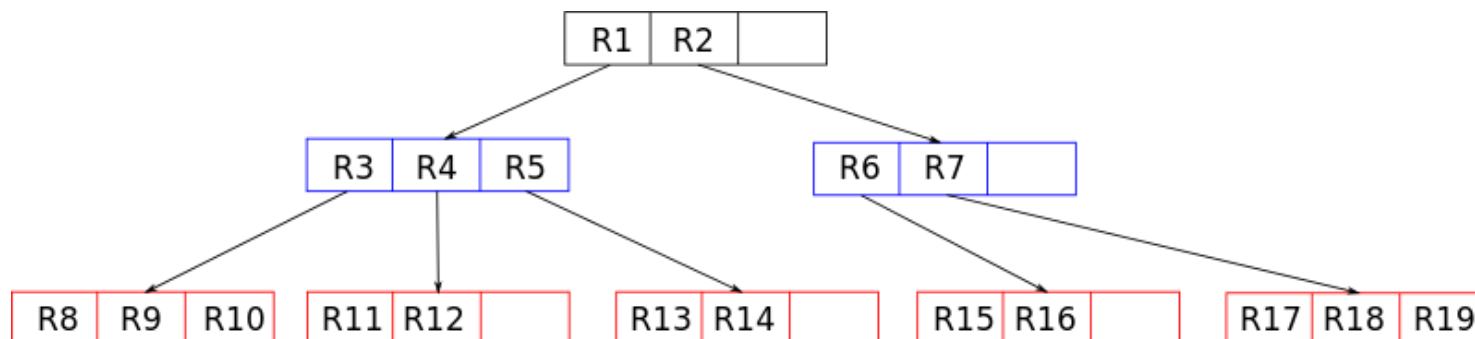
- Range query [1]
 - Find all data rectangles that are intersected by input rectangle Q
 - Result of this query just for **filter step**



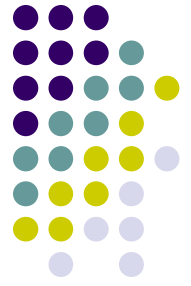
R-Tree Search



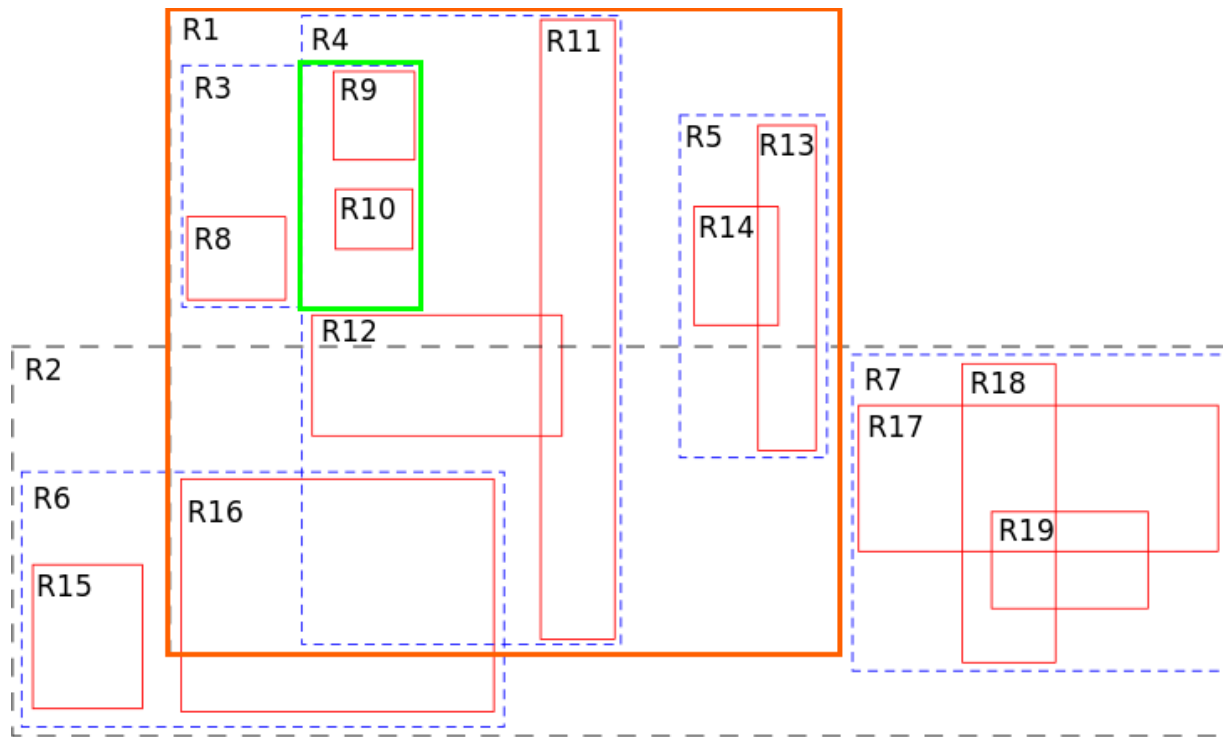
MBRs



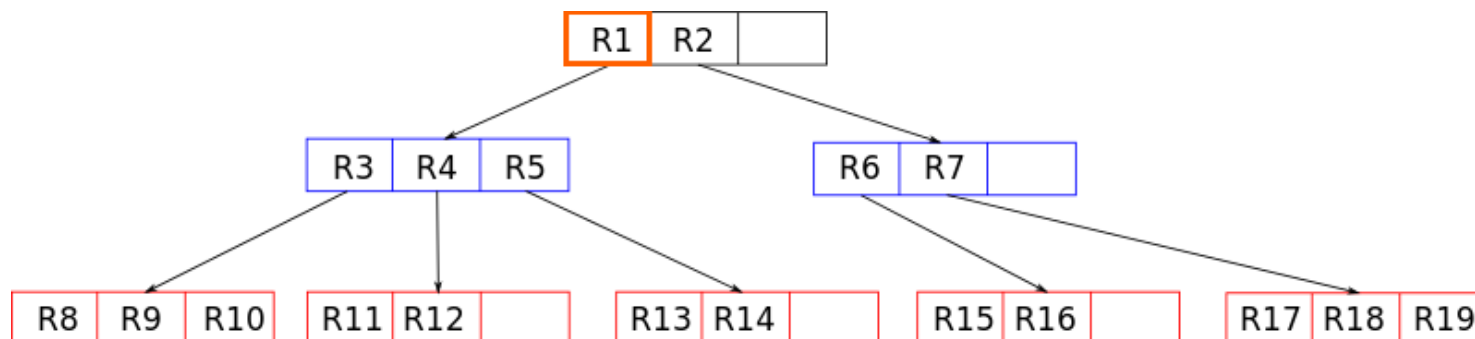
R-Tree



R-Tree Search



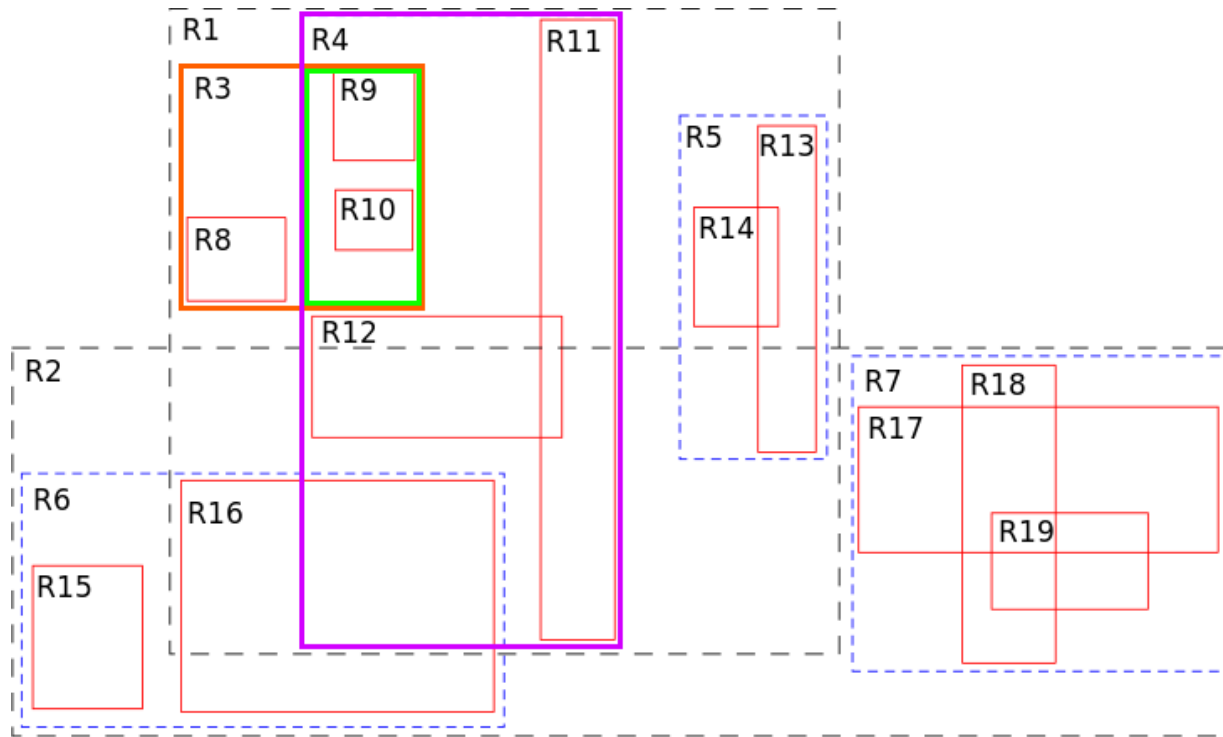
MBRs



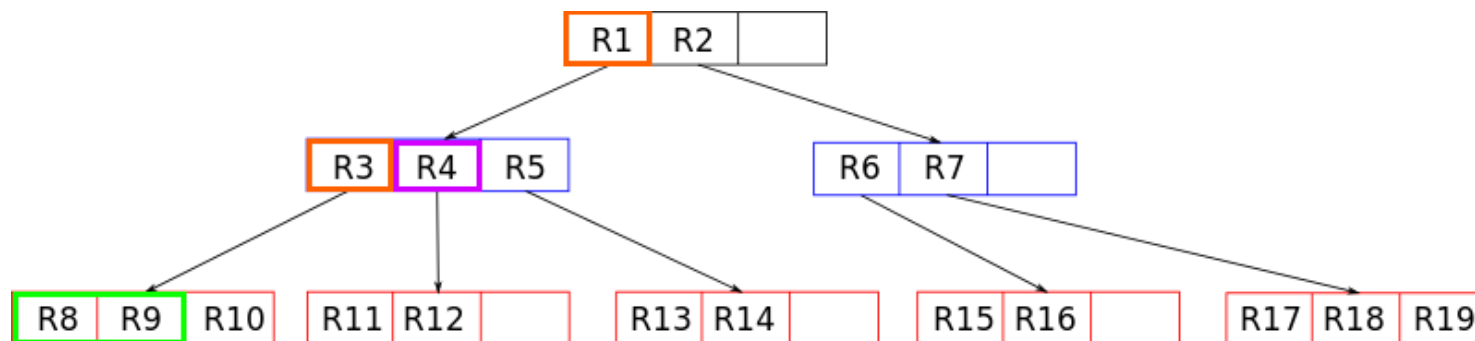
R-Tree



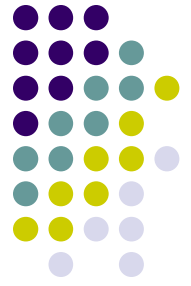
R-Tree Search



MBRs

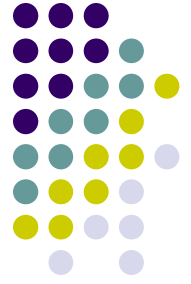


R-Tree



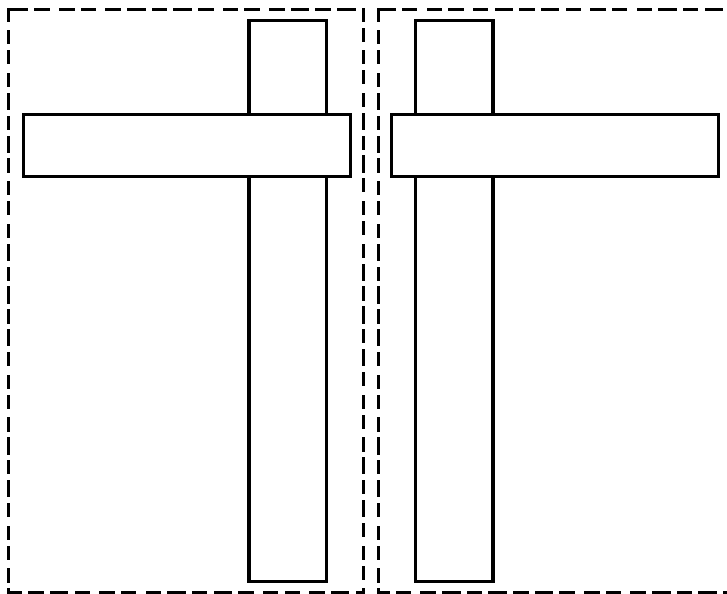
R-Tree Insertion

- Similar to insertions in B⁺-Tree
 - Traverse R-Tree to locate a leaf can hold new entry
 - Found leaf available:
 - Insert new entry into found leaf
 - Update all node within the path from root to that leaf
 - Found leaf unavailable:
 - Split node
 - How to split?

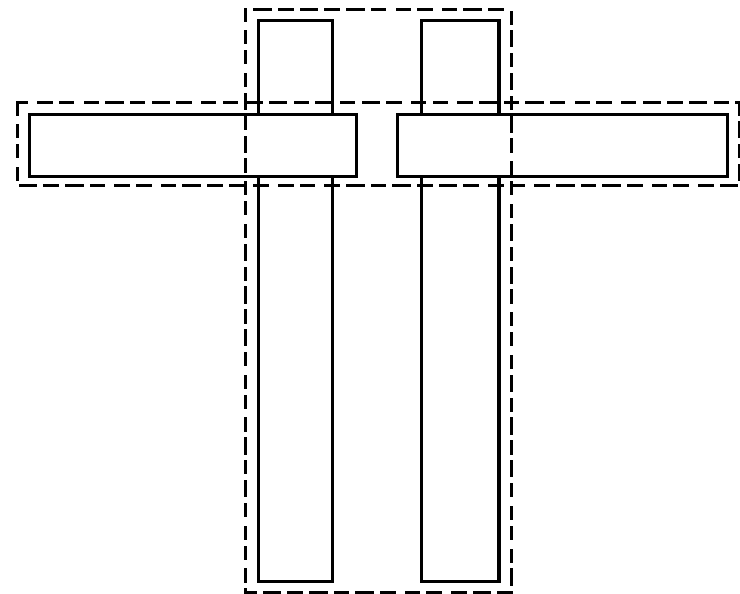


R-Tree Splitting

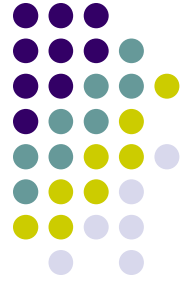
- The total area of the two covering rectangles after a split should be minimized.



Bad split

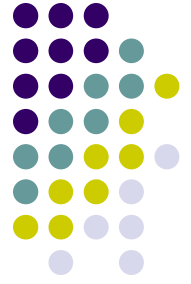


Good split



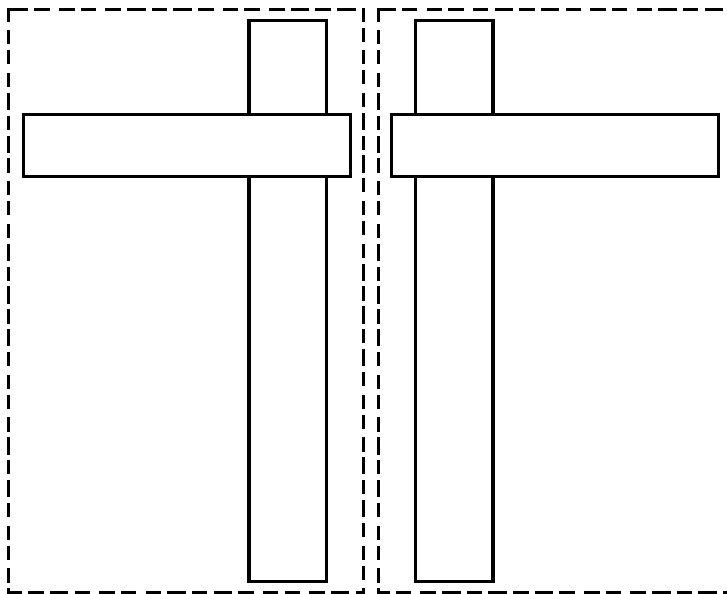
R-Tree Splitting

- 3 Splitting Algorithms (Guttman)
 - Linear split
 - Quadratic split
 - Exponential split

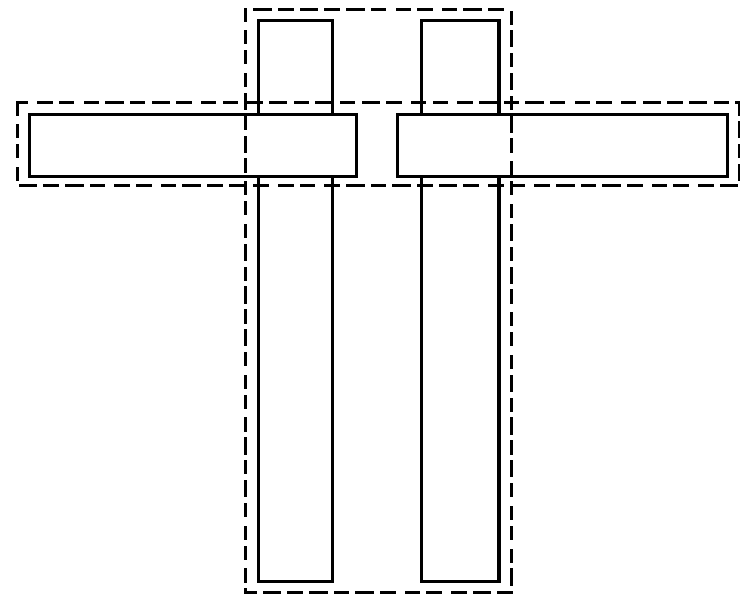


R-Tree Splitting

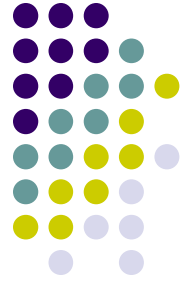
- Linear Split
 - Select objects are farthest apart
 - Require the smallest enlargement respective MBR



Bad split

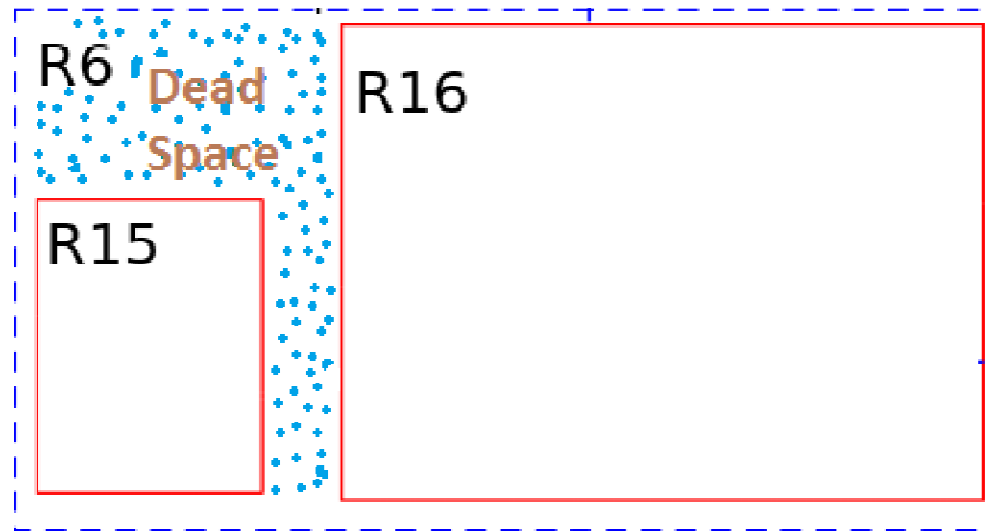


Good split



R-Tree Splitting

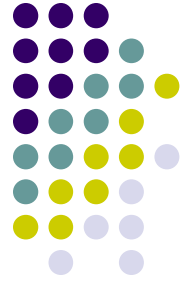
- Quadratic Split
 - Select 2 objects as seeds for the two nodes
 - Selected objects if put together create as much **dead space [1]** as possible





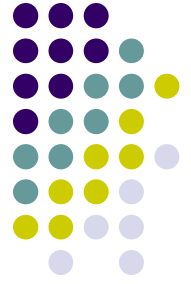
R-Tree Splitting

- Exponential Split
 - Test all possible groups
 - Choose minimization of the MBR enlargement



R-Tree Splitting

- Which splitting algorithms should be used?
 - Guttman suggested using the Quadratic splitting
- How about deleting?



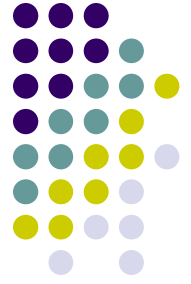
R-Tree Deletion

- Similarly to deletion in B⁺-Tree
- Handling underflowing node
 - B⁺-Tree: merging two **sibling** nodes
 - R-Tree: reinsertion



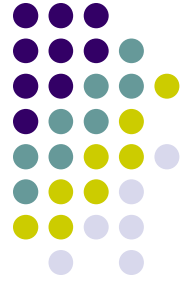
R-Tree Disadvantage

- Multiple paths from the root to the leaf level
 - Overlap MBRs
- Focus only minimized enlargement MBR
- How to improve them?

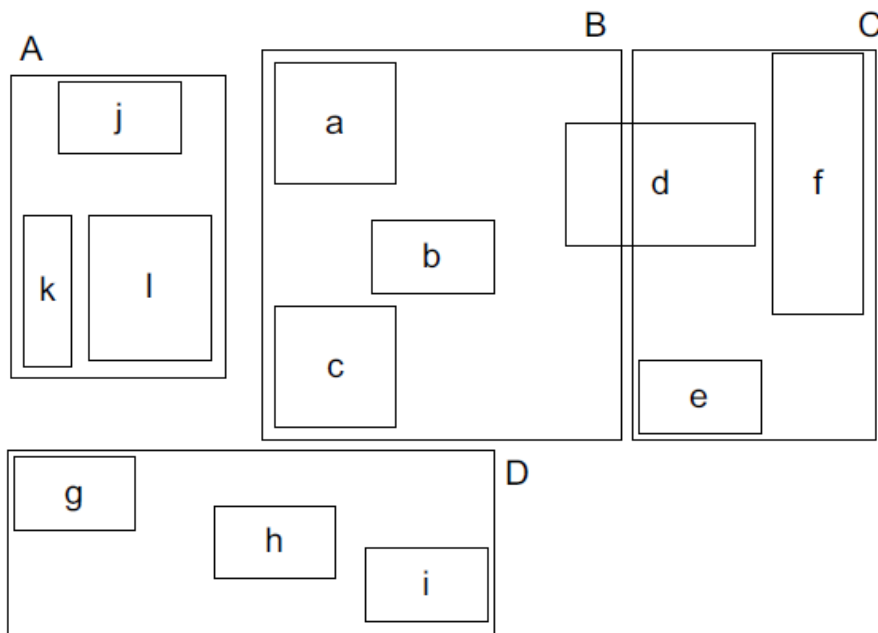


R⁺-Tree

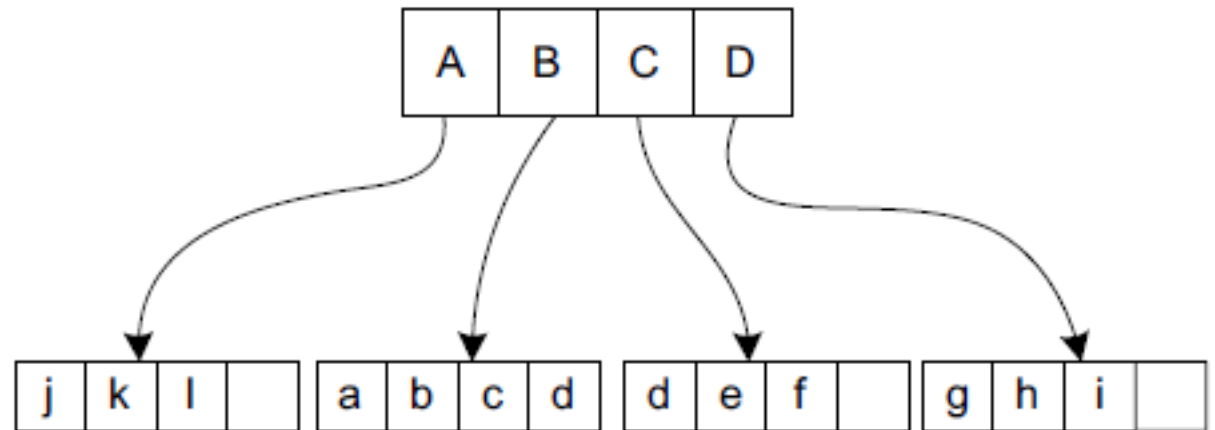
- Proposed in 1987 by Sellis, Roussopoloulos, Faloutsos
- Fix the overlapping in R-Tree



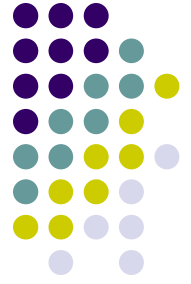
R⁺-Tree



MBRs

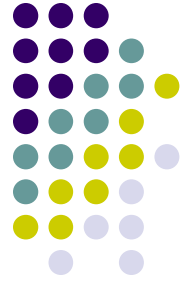


R⁺-Tree

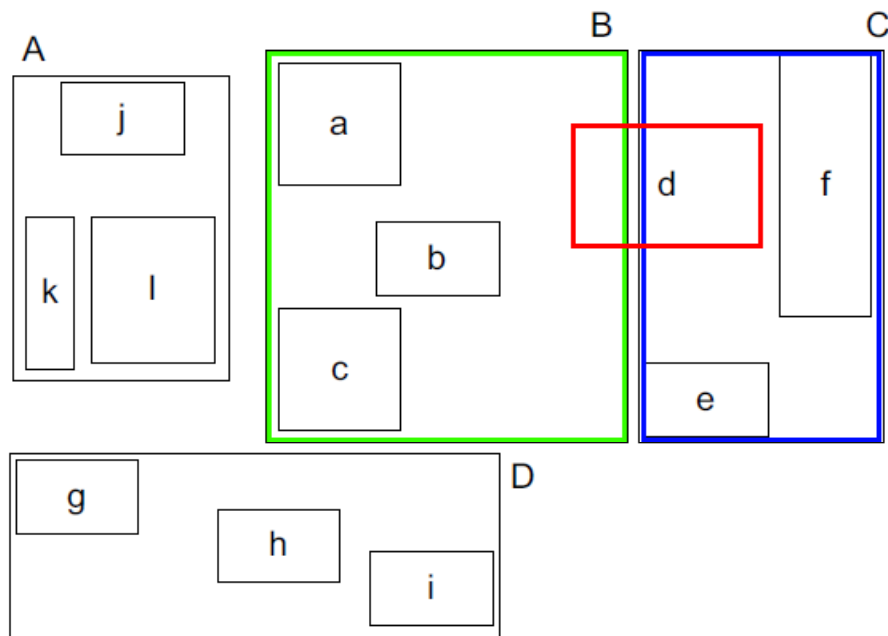


R⁺-Tree

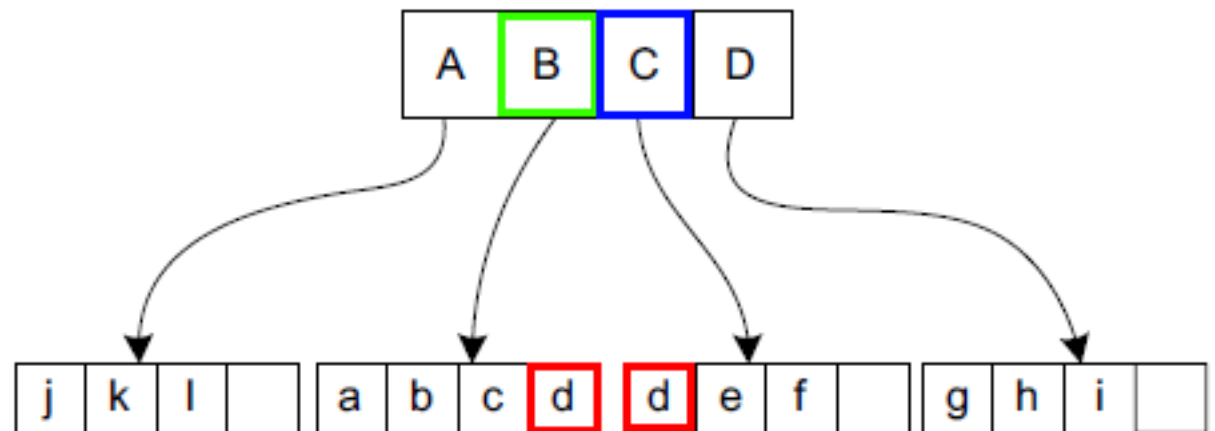
- Do not allow overlapping of MBRs at the same tree level
- May duplicate object's entries



R⁺-Tree



MBRs

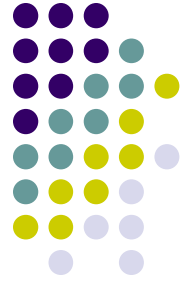


R⁺-Tree



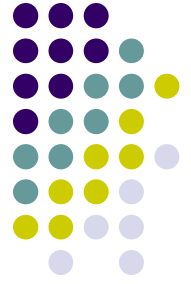
R⁺-Tree Disadvantage

- Redundantly stored in several nodes
- Performance with range queries

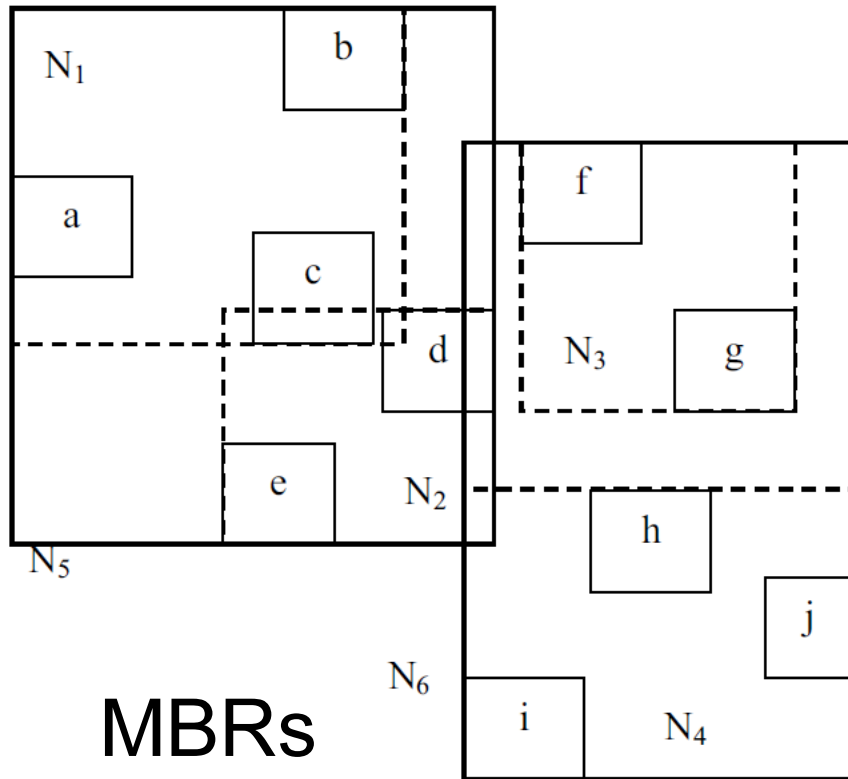


R*-Tree

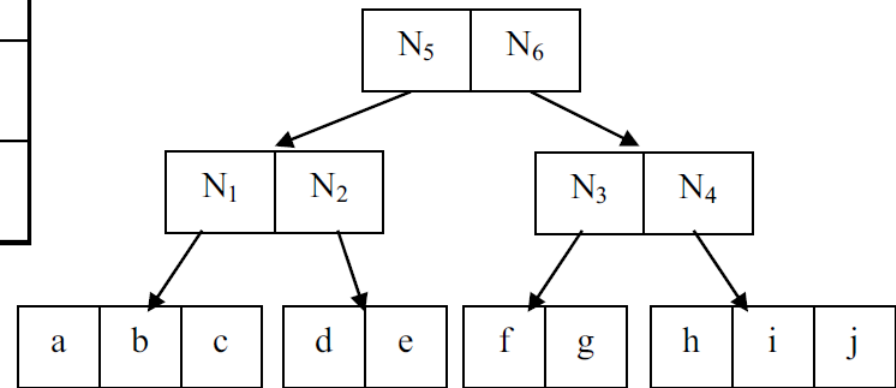
- Proposed in 1990 Beckmann, Kriegel, Schneider, Seeger
- To improve the performance during query processing



R*-Tree



MBRs

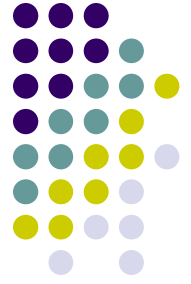


R*-Tree

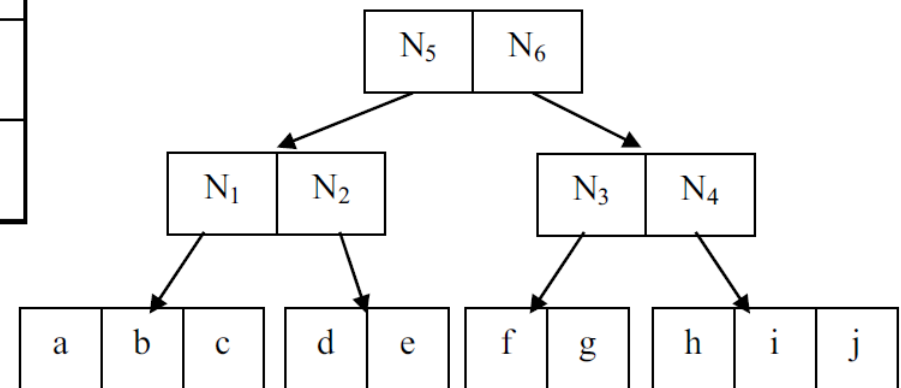
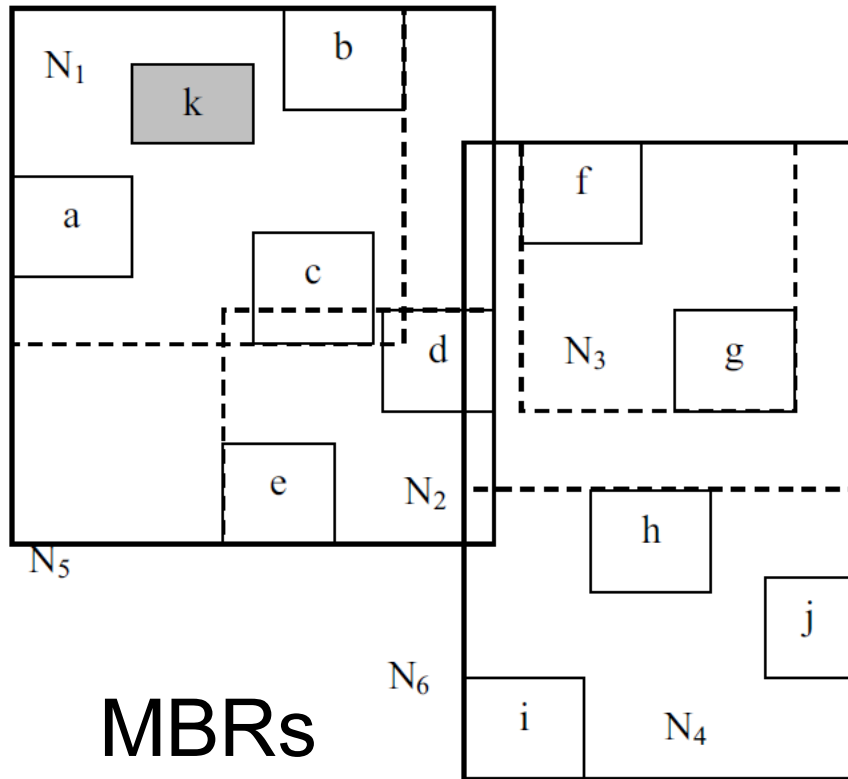


R*-Tree

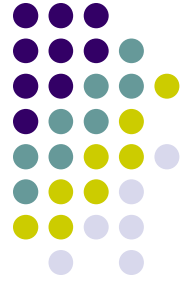
- Minimization of the area covered by each MBR (1)
- Minimization of overlap between MBRs (2)
- Minimization of MBR margins (3)
- Maximization of storage utilization (4)



R*-Tree Insertion

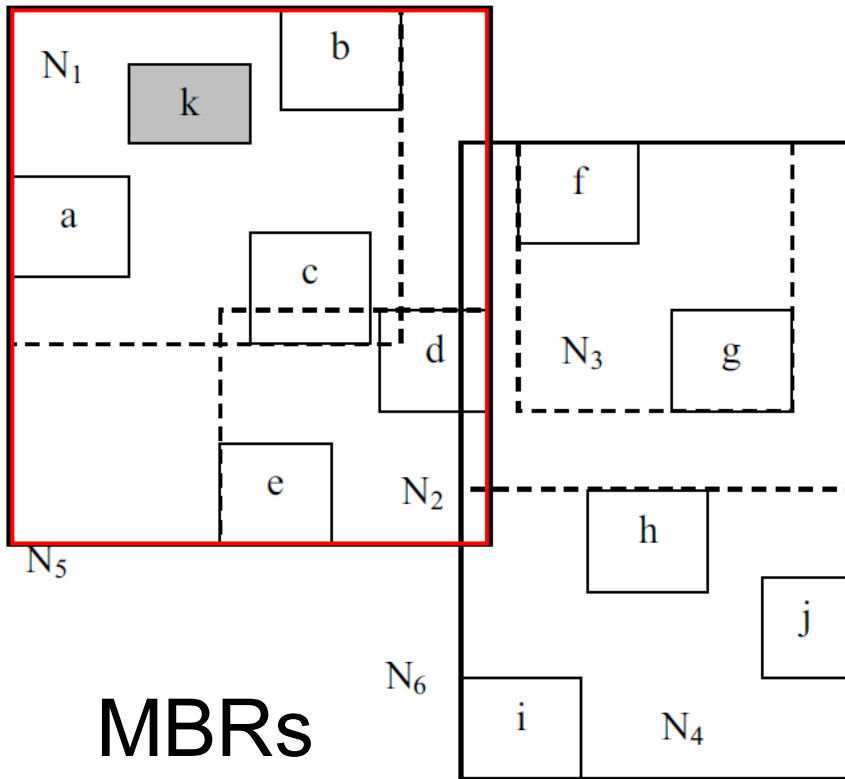


R*-Tree

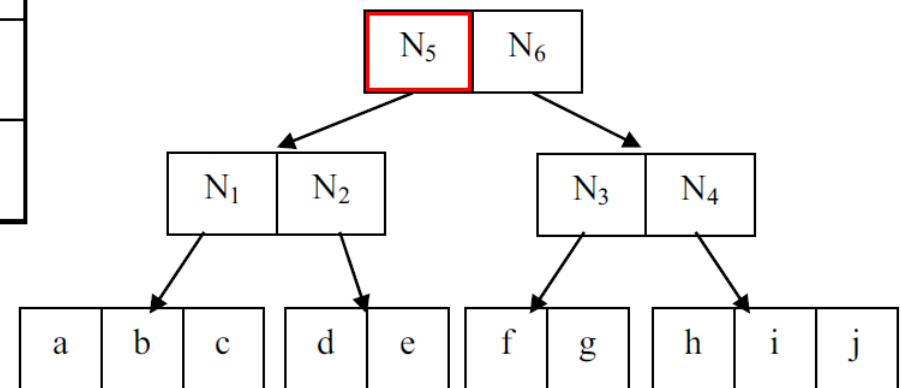


R*-Tree Insertion

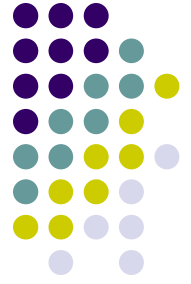
(1)



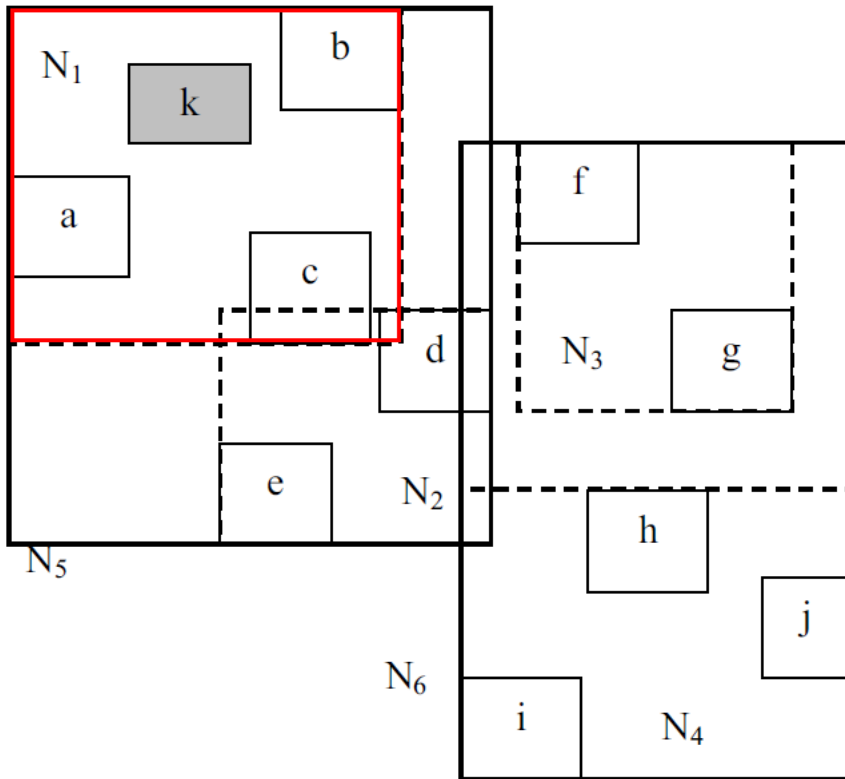
MBRs



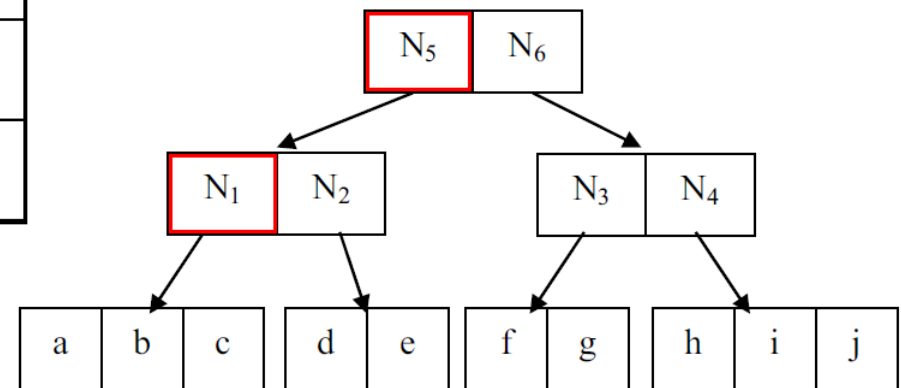
R*-Tree



R*-Tree Insertion



(1)



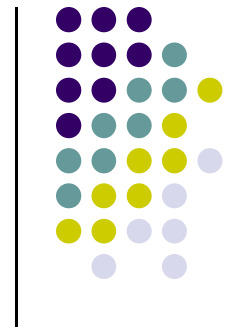
R*-Tree



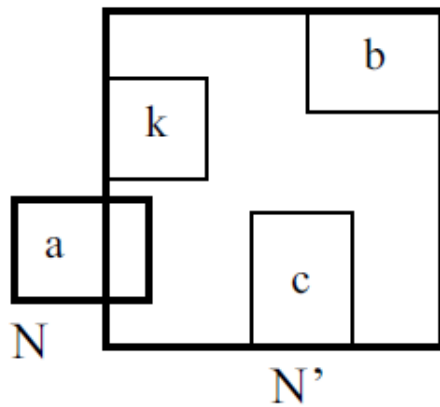
R*-Tree Insertion

- N1 overflow
 - Do not immediately resort to node splitting
 - Reinsertion
 - Get 30% entries whose centroid distances from node centroid are among the largest
 - Entry b is selected
- Reinsertion Failed → Split

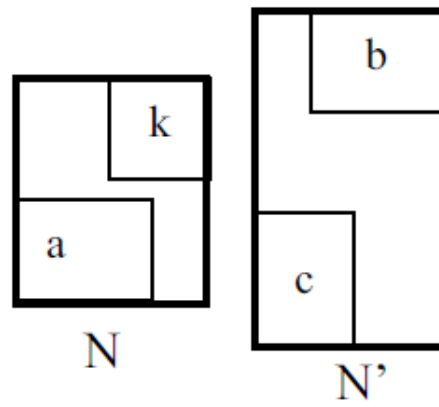
R*-Tree Splitting



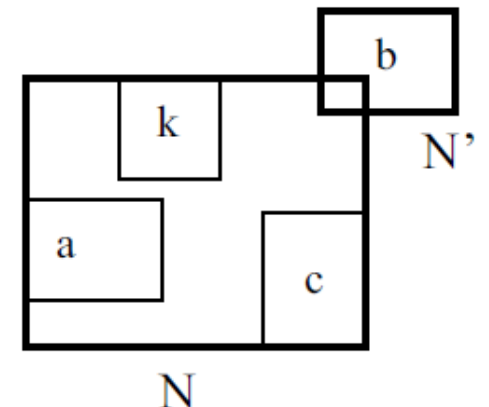
(3)



1-3 division



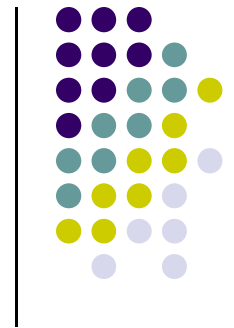
2-2 division



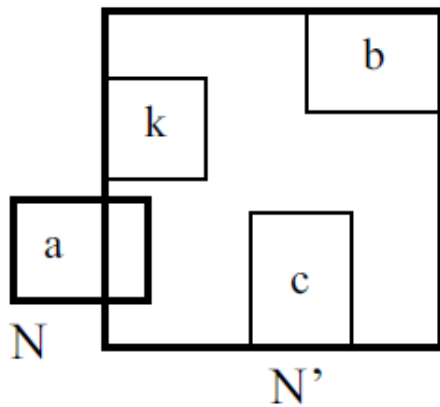
3-1 division

x-axis

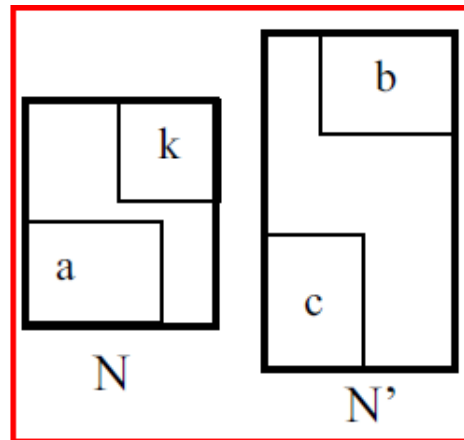
R*-Tree Splitting



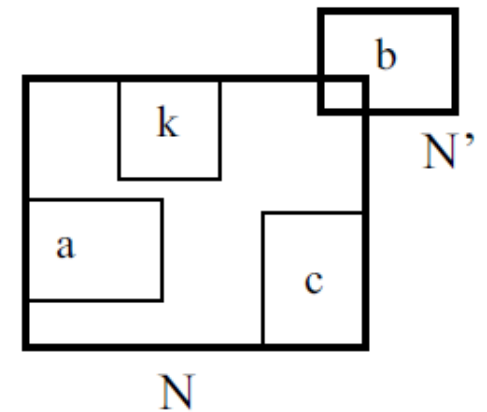
(2)



1-3 division

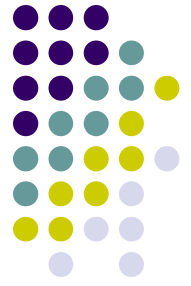


2-2 division



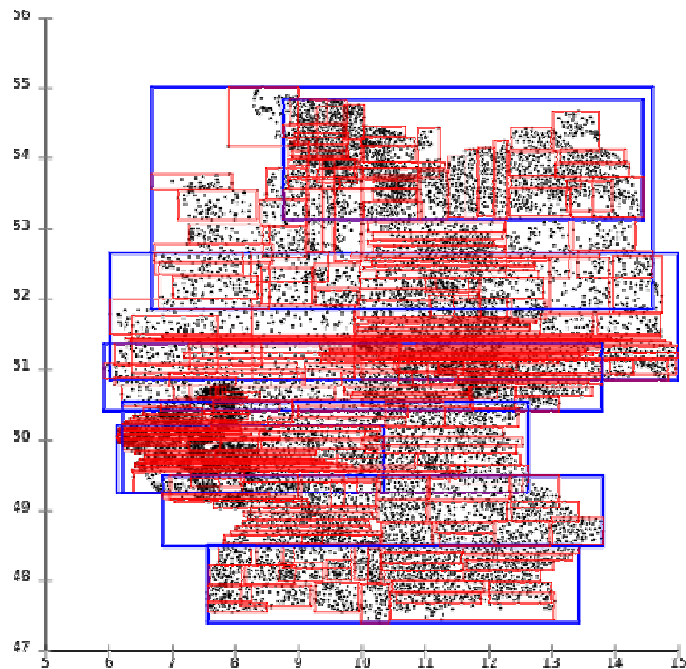
3-1 division

x-axis

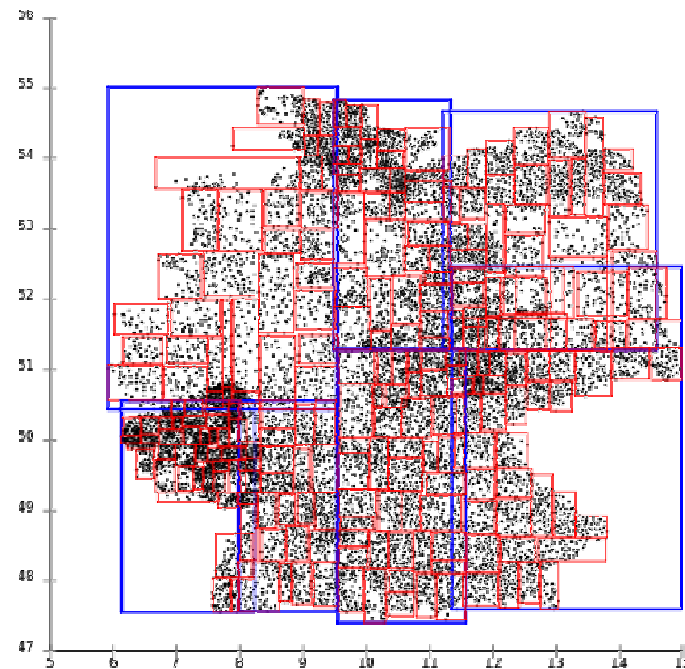


Splitting in R-Tree vs R*-Tree

R-Tree [2]



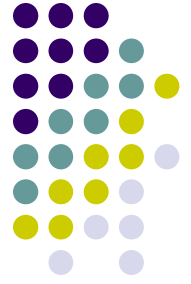
R*-Tree [2]





R*-Tree Deletion

- Deletion in the R*-Tree:
 - *Same with the deletion algorithm of the original R-tree*



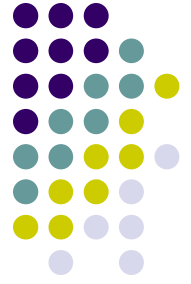
Outline

- Spatial problems in real word
- Indexing single-dimension data
- Indexing spatial data
- **Summary**
- References
- Q&A



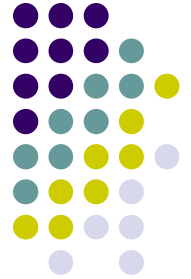
Summary

- Introducing spatial data
- Reviewing B-Tree, B⁺- Tree for single-dimension data indexing
- R-Tree, R⁺-Tree, R^{*}-Tree for spatial data indexing
- R-Tree is one of fundamental data structures to index multi-dimension data.



References

- [1] Yanniss, M., Alexandros N., *R-Tree: Theory and Applications*, Springer, 2006
- [2] http://en.wikipedia.org/wiki/R*_tree
- [3] <http://en.wikipedia.org/wiki/R-tree>
- [4] <http://www.itgsnews.com/2012/04/grade-12-revision-cad-and-cam.html>
- [5] <http://20bits.com/article/interview-questions-database-indexes>



Q&A



**Thank you for
listening!**