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# 15-826: Multimedia Databases and Data Mining

*Spatial Access Methods - V*
*Metric trees, knn methods*
C. Faloutsos

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## Outline

Goal: 'Find similar / interesting things'

- Intro to DB
- Indexing - similarity search
- Data Mining



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## Indexing - Detailed outline

- primary key indexing
- secondary key / multi-key indexing
- spatial access methods
  - problem dfn
  - z-ordering
  - R-trees
  - misc
- fractals
- text

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## SAMs - Detailed outline

- spatial access methods
  - problem dfn
  - z-ordering
  - R-trees
  - misc topics
    - grid files
    - dimensionality curse; dim. reduction
    - metric trees
    - other nn methods
- fractals
- text, ...



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## Metric trees

- What if we only have a distance function d(o1, o2)?
- (Applications?)



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## Metric trees

- (assumption: d() is a metric: positive; symmetric; triangle inequality)
- then, we can use some variation of 'Vantage Point' trees [Yannilos]
- many variations (GNAT trees [Brin95], MVP-trees [Ozsoyoglu+] ...)

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## Metric trees

- Finally: M-trees [Ciaccia, Patella, Zezula, vldb 97]
- M-trees = 'ball-trees': groups in spheres

  

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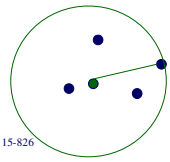
## Metric trees

- Finally: M-trees [Ciaccia, Patella, Zezula, vldb 97]
- M-trees = 'ball-trees': Minimum Bounding spheres



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## Metric trees

- Search (range and k-nn): like R-trees
- Split?

  

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## Metric trees

- Search (range and k-nn): like R-trees
- Split? Several criteria:
  - minimize max radius (or sum radii)
  - (even: random!)
- Algorithm?

  

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## Metric trees

- Search (range and k-nn): like R-trees
- Split? Several criteria:
  - minimize max radius (or sum radii)
  - (even: random!)
- Algorithm?
- eg., similar to the quadratic split of Guttman

  

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## Metric trees - variations

- Slim trees [Traina+, EDBT2000]
- OMNI tree [Filho+, ICDE2001]

  

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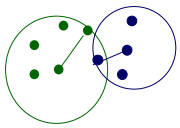
## Metric trees - Slim trees

- How to improve the structure?

BEFORE





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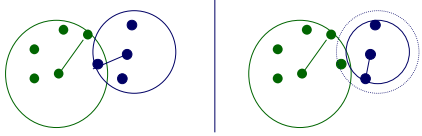
## Metric trees - Slim trees

- Idea: give-away contents, if it decreases the radius - eg:

BEFORE AFTER





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## Metric trees - Slim trees

- How to accelerate the splitting time (O(N**3), currently)?

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## Metric trees - Slim trees

- Split using Minimum Spanning Tree (drop longest edge)



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## Metric trees - Slim trees

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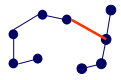



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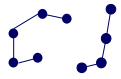
## Metric trees - Slim trees

- Split using Minimum Spanning Tree (drop longest edge)



## Metric trees - Slim trees

- result: at least as fast as M-trees for search
- MST: significantly faster for split, with tiny performance penalty



## SAMs - Detailed outline

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    - dimensionality curse; dim. reduction
    - metric trees
    - other nn methods
- fractals
- text, ...



## Metric trees - OMNI trees

- How to turn objects into vectors?
- (assume that distance computations are expensive; we need to answer range/nn queries quickly)

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## Metric trees - OMNI trees

- How to turn objects into vectors?
- A: pick *n* 'anchor' objects; record the distance of each object from them -> *n*-d vector

  

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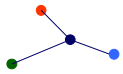

  

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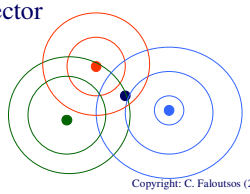

  

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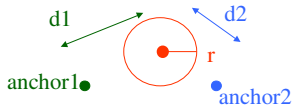
## Metric trees - OMNI trees

- we could put OMNI coordinates in R-tree (or other SAM, or even do seq. scan)
- and still answer range and nn queries! (see [Filho'01] for details)



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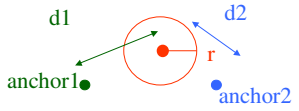
## Metric trees - OMNI trees

- Result: faster than M-trees and seq. scanning (especially if distance computations are expensive)



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## Metric trees - OMNI trees

- Q1: how to choose anchors?
- Q2: ... and how many?

  

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## Other nn methods

- Problem#1: vector space
- Problem#2: metric space



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## Other nn methods - vector space

- Solution#1: k-d trees (or R-trees etc)
- Solution#2: Constant time??

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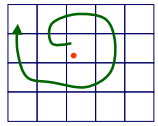
## Other nn methods - vector space

- Solution#1: k-d trees (or R-trees etc)
- Solution#2: Spiral search - put a grid; spiral out (O(1) on the average, but: exp(?) on dimension) [Bentley+, 80]



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## Other nn methods - vector space

- what if we have no index (grid / kd-tree / R-tree)?

  

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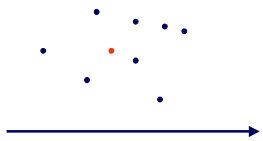
- what if we have no index (grid / kd-tree / R-tree)?
- Solution#3: [Friedman+75] Project on 1-d & sort



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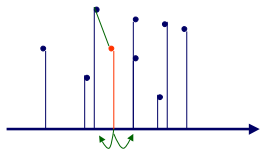



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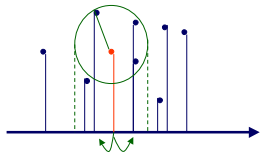



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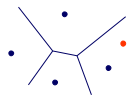
## Other nn methods - vector space

- Solution#4: Voronoi diagrams (eg., [Aurenhammer '91]



- mainly, in comp. geometry
- tricky for >=3 dimensions

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## Other nn methods

- Problem#1: vector space
- Problem#2: metric space



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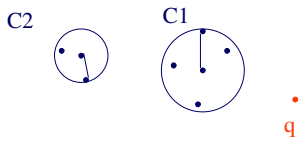
## Other nn methods - metric space

- Solution#1: Branch+Bound [Fukunaga+, '73]. Very similar to nn in M-trees:



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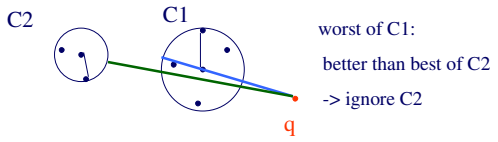
## Other nn methods - metric space

- Solution#1: Branch+Bound [Fukunaga+, '73]. Identical to nn in M-trees:




worst of C1:
better than best of C2
-> ignore C2

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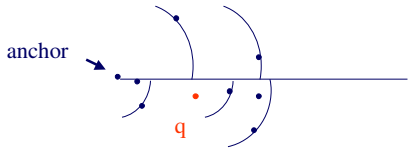
## Other nn methods - metric space

- Solution#2: Anchor points [Burkhard+, 73]



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## Other nn methods - metric space

- Solution#2: Anchor points [Burkhard+, 73]
- variations: [Shapiro, '77], [Shasha+, '90]
- related to metric trees



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## Conclusions

- Metric trees (= "sphere/ball trees") for metric spaces
  - M-trees / OMNI-trees
- several clever methods for nn search
  - branch + bound
  - anchors

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## Conclusions for SAMs

- z-ordering and R-trees for low-d points and regions
- M-trees & variants for metric datasets
- beware of the 'dimensionality curse'

  

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## References


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