CMU SCS

15-826: Multimedia Databases and Data Mining

Lecture #7: Spatial Access Methods - Metric trees

C. Faloutsos

CMU SCS

Must-read material

- MM Textbook, Chapter 5
- Roberto F. Santos Filho, Agma Traina, Caetano Traina Jr., and Christos Faloutsos: *Similarity search without tears: the OMNI family of all-purpose access methods* ICDE, Heidelberg, Germany, April 2-6 2001. (code at www.cs.cmu.edu/~christos/SRC/OmniUsrKit.tar.gz

CMU SCS

Outline

Goal: 'Find similar / interesting things'

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

CMU SCS

Indexing - Detailed outline

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

CMU SCS

SAMs - Detailed outline

- spatial access methods
  - problem dfn
  - z-ordering
  - R-trees
  - misc topics
    - metric trees
- fractals
- text, ...

CMU SCS

Metric trees

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

CMU SCS

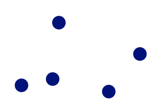
Metric trees

- (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+] ...)

CMU SCS

Metric trees

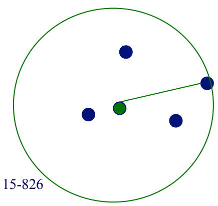
- Finally: M-trees [Ciaccia, Patella, Zezula, vldb 97]
- M-trees = 'ball-trees' : groups in spheres



CMU SCS

Metric trees

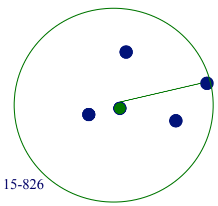
- Finally: M-trees [Ciaccia, Patella, Zezula, vldb 97]
- M-trees = 'ball-trees' : Minimum Bounding spheres

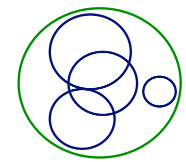


CMU SCS

Metric trees

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

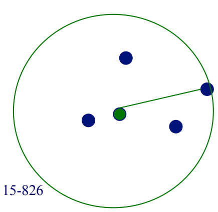


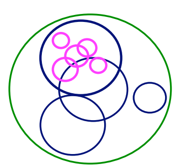


CMU SCS

Metric trees

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





CMU SCS

Metric trees

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

Metric trees

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

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

Metric trees - variations

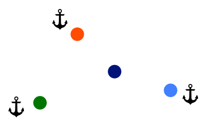
- OMNI tree [Filho+, ICDE2001]

Metric trees - OMNI trees

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

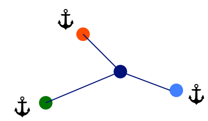
Metric trees - OMNI trees

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



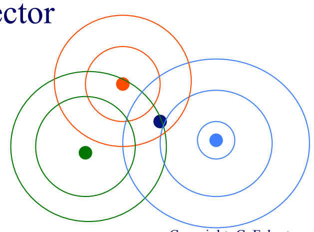
Metric trees - OMNI trees

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



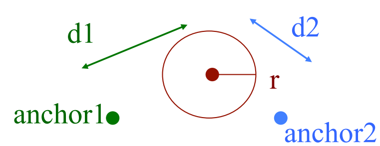
Metric trees - OMNI trees

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



Metric trees - OMNI trees

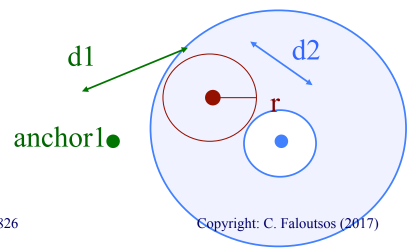
- we could put OMNI coordinates in **R-tree** (or other SAM, or even do seq. scan)
- and still answer **range** and **nn** queries! (see [Filho' 01] for details)



CMU SCS

OMNI trees – range queries

- and still answer range and nn queries! (see [Filho' 01] for details)

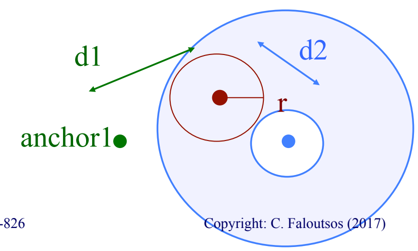


d1	d2
5.2	3.1
1.1	2.8
…	…

CMU SCS

OMNI trees – range queries

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



d1	d2
5.2	3.1
1.1	2.8
…	…

CMU SCS

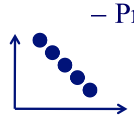
Metric trees - OMNI trees

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

CMU SCS

Conclusions for SAMs

- z-ordering and R-trees for low-d points and regions – **very** successful
- M-trees & variants for metric datasets
- beware of the 'dimensionality curse'
  - Estimate 'intrinsic' dimensionality (`fractals')
  - Project to lower dimensions ('SVD/PCA')



CMU SCS

References

- Aurenhammer, F. (Sept. 1991). "Voronoi Diagrams - A Survey of a Fundamental Geometric Data Structure." ACM Computing Surveys 23(3): 345-405.
- Bentley, J. L., B. W. Weide, et al. (Dec. 1980). "Optimal Expected-Time Algorithms for Closest Point Problems." ACM Trans. on Mathematical Software (TOMS) 6(4): 563-580.
- Burkhard, W. A. and R. M. Keller (Apr. 1973). "Some Approaches to Best-Match File Searching." Comm. of the ACM (CACM) 16(4): 230-236.

CMU SCS

References

- Christian Böhm, Stefan Berchtold, Daniel A. Keim: Searching in high-dimensional spaces: Index structures for improving the performance of multimedia databases. ACM Comput. Surv. 33(3): 322-373 (2001)
- Edgar Chávez, Gonzalo Navarro, Ricardo A. Baeza-Yates, José L. Marroquín: Searching in metric spaces. ACM Comput. Surv. 33(3): 273-321 (2001)

CMU SCS

References

- Ciaccia, P., M. Patella, et al. (1997). M-tree: An Efficient Access Method for Similarity Search in Metric Spaces. VLDB.
- Filho, R. F. S., A. Traina, et al. (2001). Similarity search without tears: the OMNI family of all-purpose access methods. ICDE, Heidelberg, Germany.
- Friedman, J. H., F. Baskett, et al. (Oct. 1975). "An Algorithm for Finding Nearest Neighbors." IEEE Trans. on Computers (TOC) C-24: 1000-1006.

CMU SCS

References

- Fukunaga, K. and P. M. Narendra (July 1975). "A Branch and Bound Algorithm for Computing k-Nearest Neighbors." IEEE Trans. on Computers (TOC) C-24(7): 750-753.
- Shapiro, M. (May 1977). "The Choice of Reference Points in Best-Match File Searching." Comm. of the ACM (CACM) 20(5): 339-343.

CMU SCS

References

- Shasha, D. and T.-L. Wang (Apr. 1990). "New Techniques for Best-Match Retrieval." ACM TOIS 8(2): 140-158.
- Traina, C., A. J. M. Traina, et al. (2000). Slim-Trees: High Performance Metric Trees Minimizing Overlap Between Nodes. EDBT, Konstanz, Germany.

