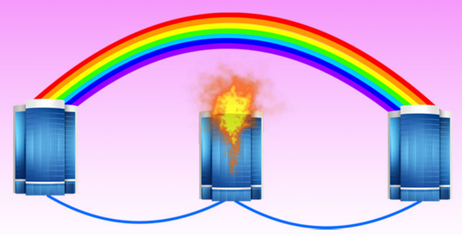
A Distributed Fault-Tolerant Spatial Data Structure

Milad Irannejad and Bradford G. Nickerson

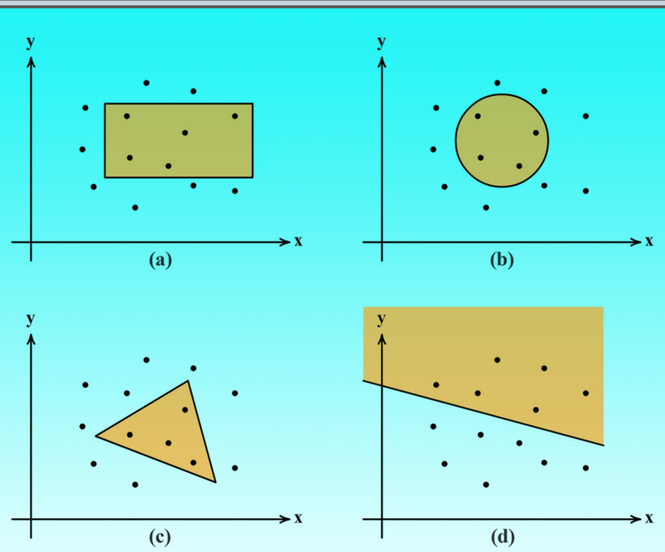
Faculty of Computer Science, University of New Brunswick, Fredericton, NB, CANADA

MOTIVATION

- Reliable data availability
- Efficient search for distributed spatial data
- Low number of messages
- Optimal 2D search under the distributed computing model?

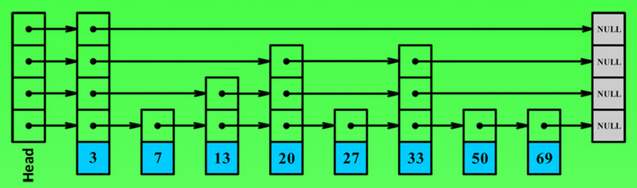


RANGE SEARCH



In each figure, the shaded area is a sample range of R^2 area.
(a) Rectangle (b) Ball (c) Simplex (d) Halfspace

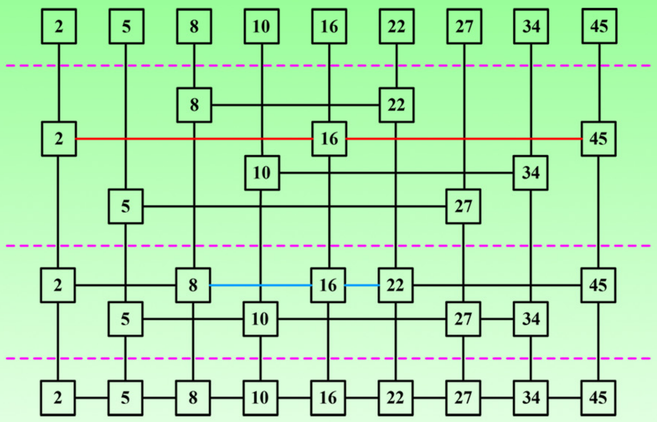
ONE DIMENSIONAL INDEXING



Skip List

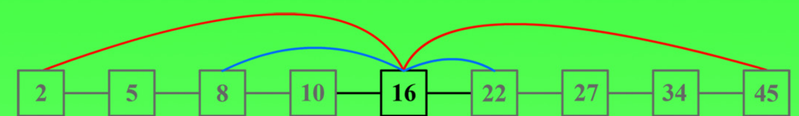
- Searches can start from any node
- Average space: $O(n)$
- Average single key search time (W.H.P.): $O(\log n)$
- Range search costs: $O(\log n + k/B)$ messages
  - k: number of points in range
  - B: number of points in one message

In all above, n is the number of nodes.

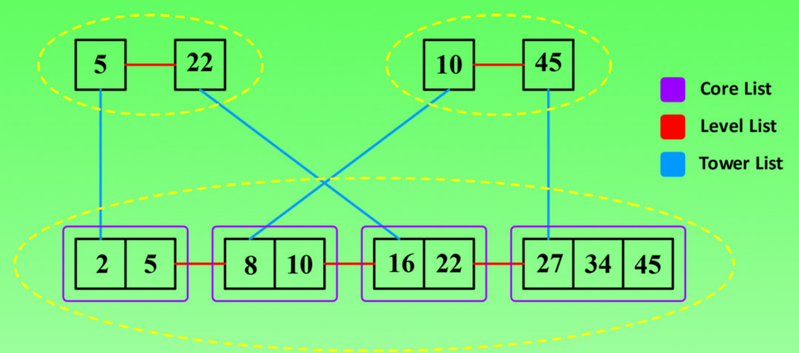


Skip Graph [1]

- Distributed extension of skip lists
- Being used in searching P2P networks
- Can tolerate some fraction of node failures
- Single key search requires $O(\log n)$ messages and $O(\log n)$ time

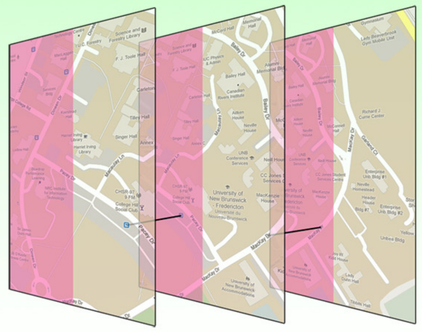


Multiple list membership of each node

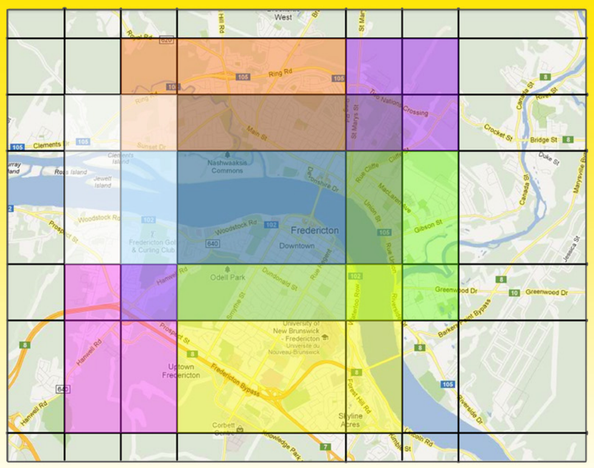


Non-Redundant Rainbow Skip Graph [2]

- A skip graph on $\theta(n / \log n)$ supernodes
- A supernode consists of $\theta(\log n)$ nodes
- Fixed number of pointers per node vs. skip graph with $O(\log n)$
- Worst case cost for 2D range search: $O(n + k/B)$ messages
- Worst case 2D range search cost: $O(n)$ message



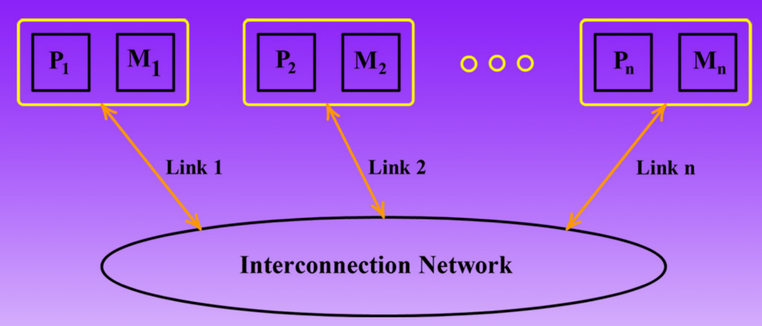
POSSIBLE DATA DISTRIBUTION



Overlapping Adaptive Grid File [3]

- An *adaptable*, *symmetric multikey* file structure.
- Stores highly dynamic sets of multidimensional data
- Queries can be performed using few disk accesses.
- Partitions a k-dimensional data space according to an orthogonal grid
- In a range search, all records which lie in the Cartesian product C of intervals are retrieved

DISTRIBUTED COMPUTING MODEL



Message Passing Architecture

- A node consists of a processor and its local memory
- Each processor has access to its own local memory.
- Communications are performed via send and receive P2P operations.

[1] Michael T.Goodrich, Michael J. Nelson, and Jonathan Z. Sun, The rainbow skip graph: a fault-tolerant constant-degree distributed data structure, SODA '06 Proceedings of the seventeenth annual ACM-SIAM symposium on Discrete algorithm, pp. 384-393
[2] Bisadi, Pouya and Nickerson, Bradford G. "Orthogonal Range Search using a Distributed Computing Model", Proc. of the 23rd Canadian Conference on Computational Geometry (CCCG 2011), Toronto, Ontario, Aug. 10-12, 2011, pp.337-342.
[3] Klaus Hinrichs, Implementation of the grid file: Design concepts and experience, BIT Numerical Mathematics, 1985, Volume 25, Issue 4, pp. 569-592

Sponsored by: UNB Faculty of COMPUTER SCIENCE, NSERC CRSNG