CSE 326: Data Structures
Other Self-balancing BSTs

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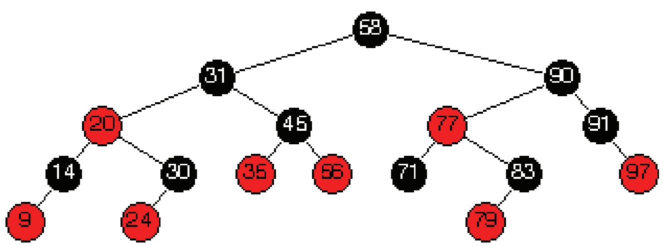
Announcements (5/5/08)

- Project 2B due Wednesday night.
- Midterms will be graded this week, returned to you in section.
- Homework 4 due Friday, beginning of class.

Red-Black Trees

Structure property:

- Every node is "colored" either **red** or **black**.
- The root is **black**.
- If a node is **red**, its children must be **black**. (A leaf can be red.)
- Every path from a node to a null reference must contain



Red-Black Trees

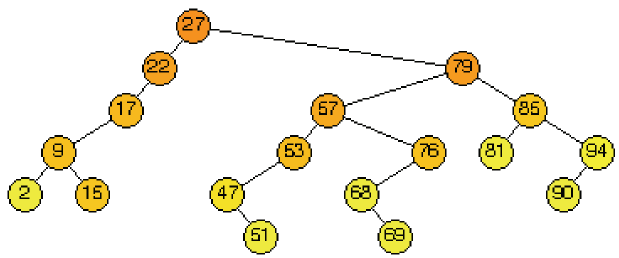
Notes:

- Uses the standard rotations, plus some coloring operations, to maintain structure.
- **Worst case** find, insert, delete: O(log *n*)
- Has nice top-down, non-recursive implementation.
- Java uses top-down red-black trees.

Treaps

Order property:

- Each node has a randomly assigned priority value, in addition to its key value.
- Tree has both BST and heap order!



Orange = low priority value, Yellow = high priority value

Treaps

Notes:

- Insert:
  - insert as leaf
  - assign random priority
  - percolate up with rotations.
- Delete:
  - set priority to infinity
  - percolate down with rotations
  - once it's a leaf, delete.
- **Average case** insert, delete, find: O(log *n*).

There are many more…

There are many more sorted Dictionary ADTs:

- AA trees
- Scapegoat trees
- Skip lists
- …

Experimental evaluation

Pfaff [1] tried out 20 different BSTs on several common systems applications.

Findings:

- Random inputs:
  - BSTs perform best (low overhead)
- Mostly random inputs, occasional ordering:
  - Red-Black trees best
- Ordered inputs, random finds
  - AVL trees best
- Ordered inputs, ordered or clustered finds:
  - Splay trees best (though not best for interactive situations)

Special queries

The BSTs we've discussed were only required to support the Dictionary ADT: find, insert, delete.

But, other operations that leverage the sorted data can also be efficient on BSTs:

- findMax
- findMin
- findMedian
- findRange (i.e., keys within a certain range)
- printSorted

Bibliography

[1] Pfaff, B. Performance Analysis of BSTs in System Software. 2004. In *ACM SIGMETRICS Performance Evaluation Review*, vol. 32, pp. 410-411 (extended abstract). Full paper available online.