

CSE-4411

Database Management Systems

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Fall 2005

Tree-based Indexes



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Tree-based Indexes

Okay, there are plenty of data-structures for balanced search trees: e.g., AVL trees, red-black trees, skew trees. So what is the difficulty? Let's just use one.

Difficulties:

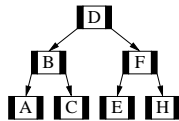
- Tree may be too big for main memory.
 - Need to be careful about #I/O's for *searches*, *inserts*, and *deletes*.
 - Must group information by page.
- Tree may be too deep to be efficient.

Can any techniques we know be adapted?

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Balanced Binary Trees

Consider we have N records to store.

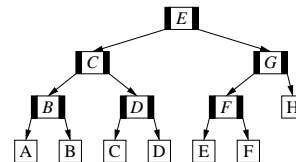


What is the *height* (depth) H of the shallowest possible, balanced binary tree, if we keep data / records in leaf *and* non-leaf nodes?

$$\lceil \log_2(N + 1) \rceil$$

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Balanced Binary Trees

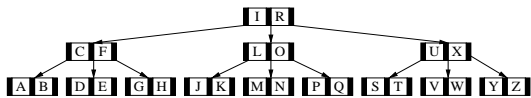


What is the *height* (depth) H of the shallowest possible, balanced binary tree, if we keep data / records *only* in leaf nodes?

$$\lceil \log_2 N \rceil + 1$$

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Balanced K-ary Trees

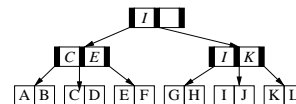


What is the *height* (depth) H of the shallowest possible, balanced K-ary tree, if we keep data / records in leaf *and* non-leaf nodes?

$$\lceil \log_K(N + 1) \rceil$$

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Balanced K-ary Trees



What is the *height* (depth) H of the shallowest possible, balanced K-ary tree, if we keep data / records *only* in leaf nodes?

$$\lceil \log_K N \rceil + 1$$

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K-ary Trees!

- If K is large, the height of the tree will be small! We shall rename K as F —as the textbook uses—for *fan-out*.
 - Make a *node* the size of a page.
- So does F really save us anything?
 - Not on #comparisons, but *yes* on #I/O's:
 - $(\log_2 F)(\log_F N/R) = \log_2 N/R$ comparisons still,
 - but just $\log_F N/R$ I/O's.
 - ($N = \#$ records in all, $R = \#$ records per page.)
- Design choice: Okay, should we keep records in non-leaves or not?
- How do we keep an F -ary tree balanced on *inserts* and *deletes*?

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B Trees & B+ Trees

- The **B tree** and, subsequently, the **B+ tree** models are K -ary tree models with a particular balance rule.
 - For B trees, records (or data entries) are kept in non-leaf nodes *and* leaf nodes.
 - For B+ trees, records (or data entries) are kept just in leaf nodes (*data pages*). Non-leaf nodes are called *index pages*.
- We *trade off* space for the balance strategy: Each node (equal to a page) can be up to half empty.
- All leaves are at the same depth.
 - Tree grows when a leaf page is split, and when the index pages up to the root must consequently be split.

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B Trees versus B+ Trees

Advantages of B trees:

- May use fewer tree nodes than a corresponding B+ tree.
- Sometimes possible to find the search-key value *before* reaching a leaf node.

Advantages of B+ trees:

- Only a *small* fraction of searches are found *before* a leaf page.
- Non-leaf pages can contain more index keys than the B tree's non-leaf page can contain records (or entries), so the fan-out (F) is more.
- Insertion and deletion is easier.
- implementation is easier.

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