CS422 Principles of Database Systems

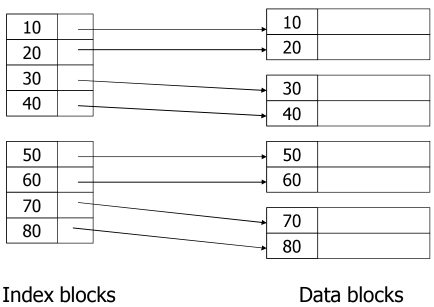
Indexes

Chengyu Sun
California State University, Los Angeles

Indexes

- Auxiliary structures that speed up operations that are not supported *efficiently* by the basic file organization

A Simple Index Example



Entries in an Index

- <key, rid>
- <key, list of rid>
- Data records

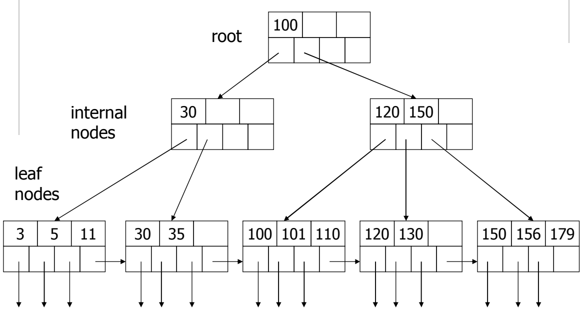
Organization of Index Entries

- Tree-structured
  - B-tree, R-tree, Quad-tree, kd-tree, …
- Hash-based
  - Static, dynamic
- Other
  - Bitmap, VA-file, …

From BST to BBST to B

- Binary Search Tree
  - Worst case??
- Balance Binary Search Tree
  - E.g. AVL, Red-Black
- B-tree
  - Why not use BBST in databases??

B-tree (B⁺-tree) Example



B-tree Properties

- Each node occupies one block
- Order `n`
  - `n` keys, `n+1` pointers
- Nodes (except root) must be at least half full
  - Internal node: $\lceil (n+1)/2 \rceil$ pointers
  - Leaf node: $\lfloor (n+1)/2 \rfloor$ pointers
- All leaf nodes are on the same level

B-tree Operations

- Search
- Insert
- Delete

B-tree Insert

- Find the appropriate leaf
- Insert into the leaf
  - there's room → we're done
  - no room
    - split leaf node into two
    - insert a new <key,pointer> pair into leaf's parent node
- *Recursively apply previous step if necessary*
  - A split of current ROOT leads to a new ROOT

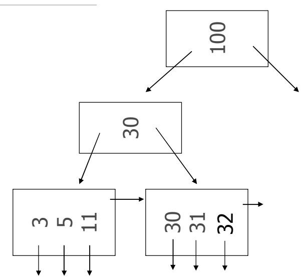
B-tree Insert Examples

- (a) simple case
  - space available in leaf
- (b) leaf overflow
- (c) non-leaf overflow
- (d) new root

HGM Notes

(a) Insert key = 32

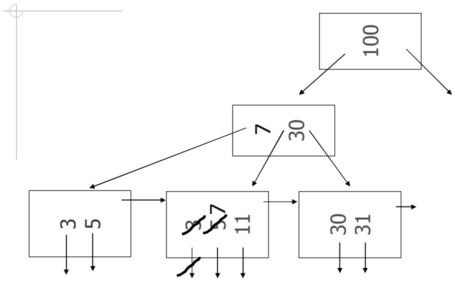
n=3



HGM Notes

(b) Insert key = 7

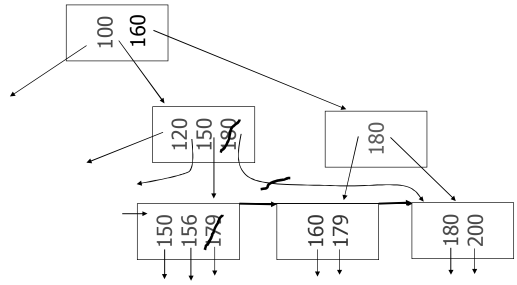
n=3



HGM Notes

(c) Insert key = 160

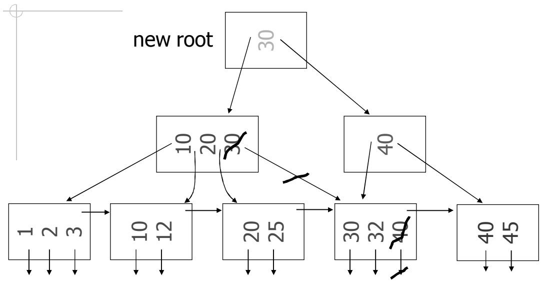
n=3



HGM Notes

(d) New root, insert 45

n=3



HGM Notes

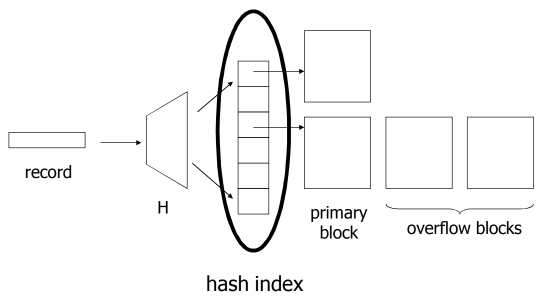
B-tree Delete

- Find the appropriate leaf
- Delete from the leaf
  - still at least half full → we're done
  - below half full – coalescing
    - borrow a <key,pointer> from one sibling node, *or*
    - merge with a sibling node, and delete from a parent node
- Recursively apply previous step if necessary

B-tree Delete in Practice

- Coalescing is usually not implemented because it's too hard and not worth it

Static Hash Index



Hash Function

- A commonly used hash function: `K%B`
  - `K` is the key value
  - `B` is the number of buckets

Dynamic Hashing

- Problem of static hashing??
- Dynamic hashing
  - Extendable Hash Index

Extendable Hash Index …

- 2^M buckets
  - M is maximum depth of index
- Multiple buckets can share the same block
  - Empty buckets do not take up space
  - Buckets are indexed by a bucket directory

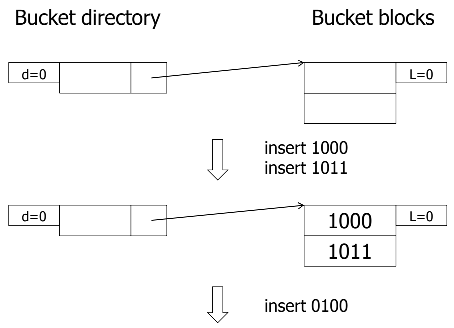
… Extendable Hash Index

- Each block has a local depth `L`, which means that the hash values of the records in the block has the same rightmost `L` bit
- The bucket directory keeps a global depth `d`, which is the highest local depth

Extendable Hash Index Example

- M = 4
- Hash function: K % 2^4
- 2 index entries per block

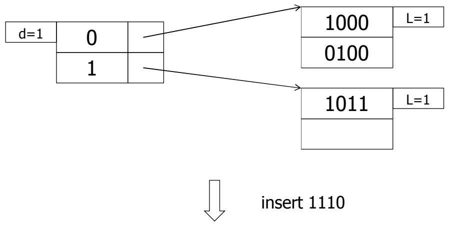
Extendable Hashing (I)



Extendable Hashing (II)

Bucket directory

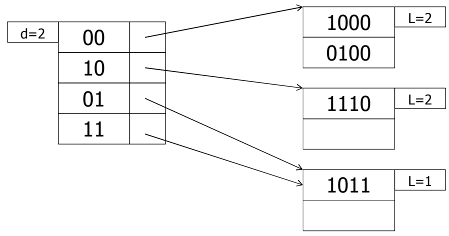
Bucket blocks



Extendable Hashing (III)

Bucket directory

Bucket blocks



Readings

- Textbook Chapter 21.1 – 21.4