Tree-Structured Indexes

CMPSCI 445

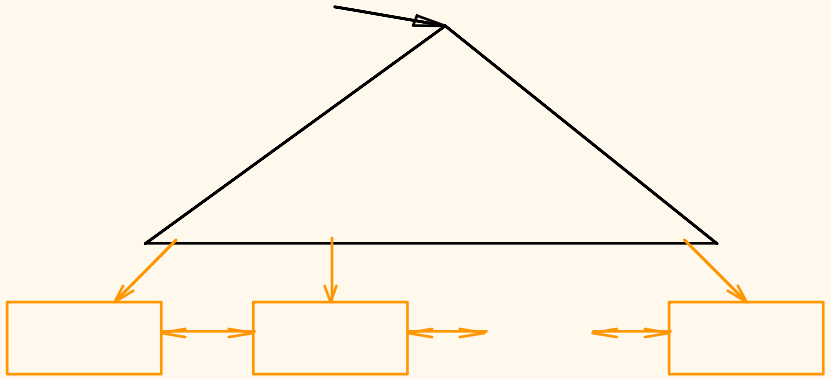
Fall 2008

Review

- *As for any index, 3 alternatives for data entries* **k***:
  - Data record with key value **k**
  - <**k**, rid of data record with search key value **k**>
  - <**k**, list of rids of data records with search key **k**>
- Choice is orthogonal to the *indexing technique* used to locate data entries **k***.
- Tree-structured indexing techniques support both *range searches* and *equality searches*.

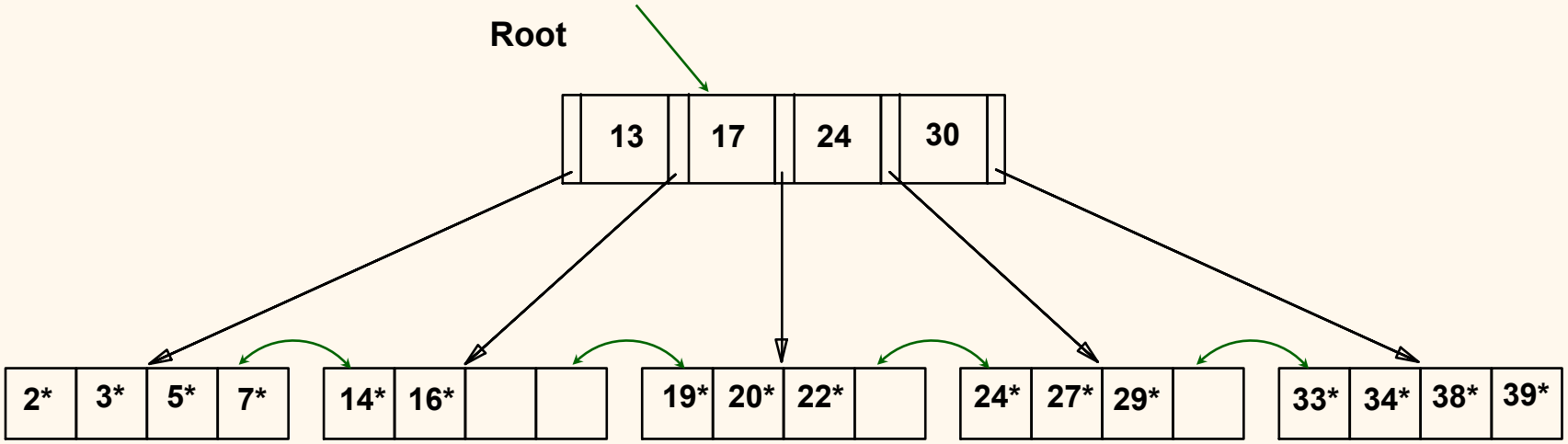
B+ Tree: Most Widely Used Index

- Inserts/deletes keep tree *height-balanced*. Log $_F$ N cost (F = fanout, N = # leaf pages).
- Minimum 50% occupancy (except for root). Each node contains **d** <= *m* <= 2**d** entries, where **d** is called the *order* of the tree.
- Supports equality, range-searches, updates efficiently.



Example B+ Tree

- Search begins at root, and key comparisons direct it to a leaf.
- Search for 5*, 15*, all data entries >= 24* ...



☛ *Based on the search for 15*, we know it is not in the tree!*

B+ Trees in Practice

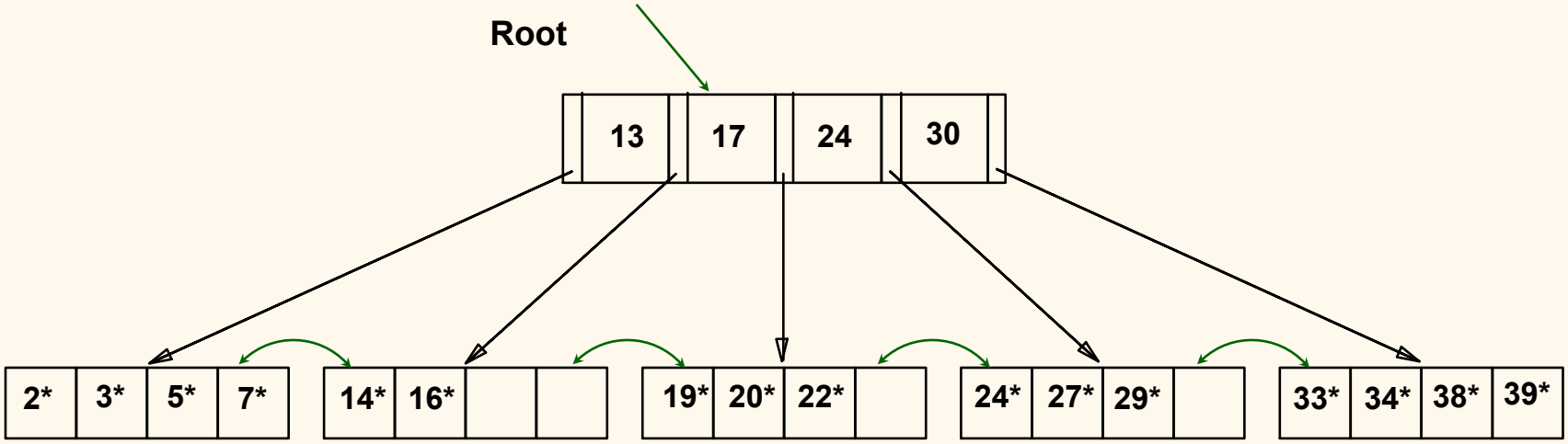
- Typical order: 100. Typical fill-factor: 67%.
  - average fanout = 133
- Typical capacities:
  - Height 4: 133^4 = 312,900,700 records
  - Height 3: 133^3 = 2,352,637 records
- Can often hold top levels in buffer pool:
  - Level 1 = 1 page = 8 Kbytes
  - Level 2 = 133 pages = 1 Mbyte
  - Level 3 = 17,689 pages = 133 MBytes

Inserting a Data Entry into a B+ Tree

- Find correct leaf *L*.
- Put data entry onto *L*.
  - If *L* has enough space, *done*!
  - Else, must *split* *L (into L and a new node L2)*
    - Redistribute entries evenly, **copy up** middle key.
    - Insert index entry pointing to *L2* into parent of *L*.
- This can happen recursively
  - To split index node, redistribute entries evenly, but **push up** middle key. (Contrast with leaf splits.)
- Splits "grow" tree; root split increases height.
  - Tree growth: gets *wider* or *one level taller at top.*

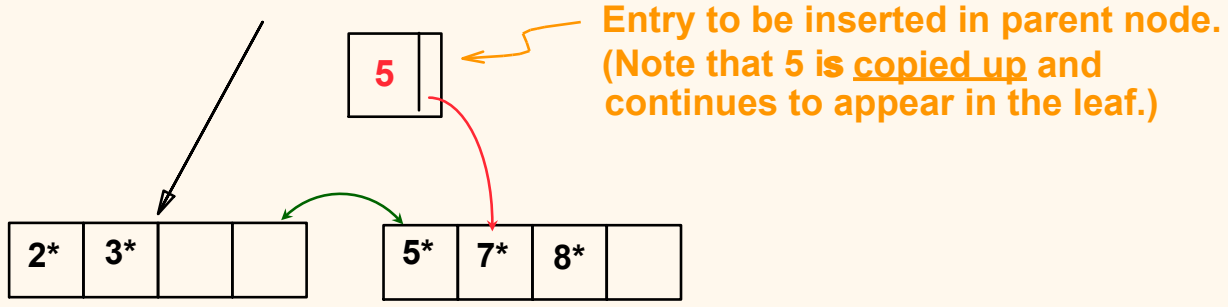
Previous Example

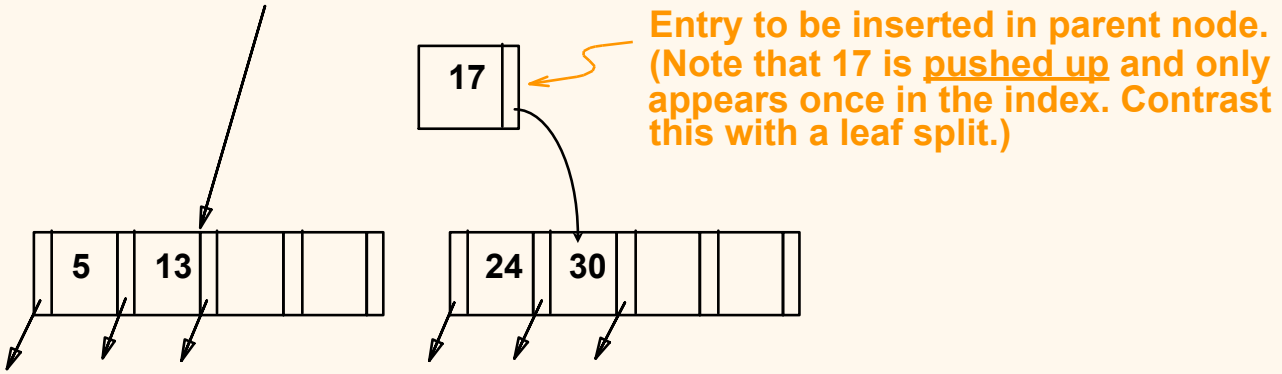
Inserting 8*



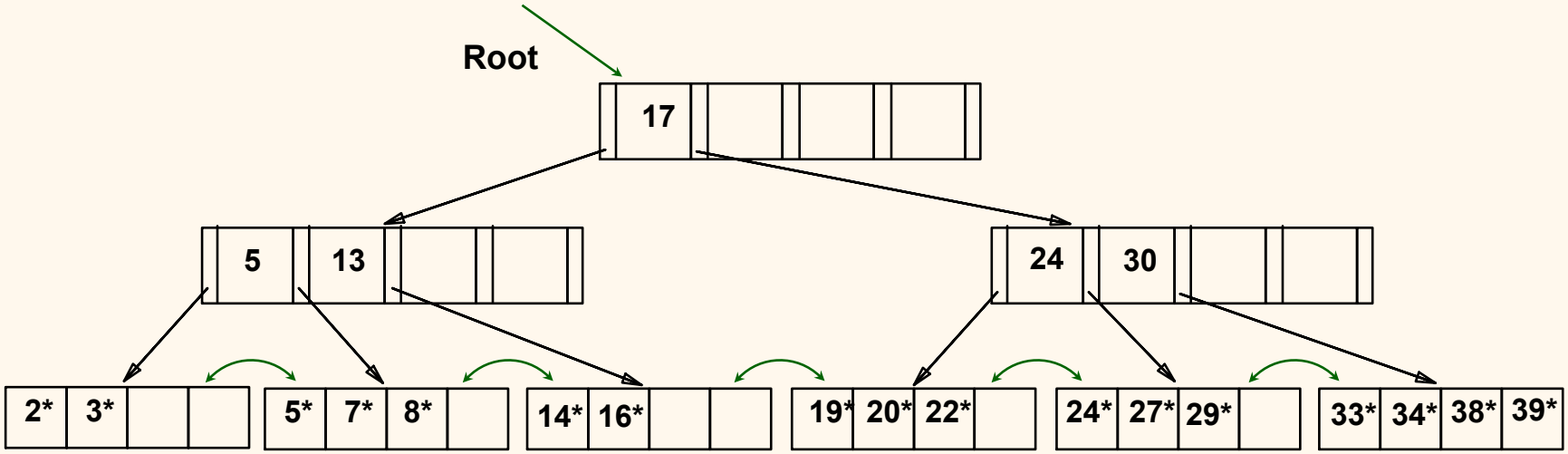
Inserting 8 into Example B+ Tree*

- Observe how minimum occupancy is guaranteed in both leaf and index pg splits.
- Note difference between *copy-up* and *push-up;* be sure you understand the reasons for this.





*Example B+ Tree After Inserting 8**



- Notice that root was split, leading to increase in height.
- In this example, we can avoid split by re-distributing entries between siblings; but not usually done in practice.