Lecture 21: B-Trees

Monday, Nov. 19, 2001

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Outline

- B+ trees (4.3)

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B+ Trees

- Search trees
- Idea in B Trees:
  - make 1 node = 1 block
- Idea in B+ Trees:
  - Make leaves into a linked list (range queries are easier)

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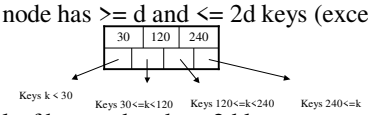
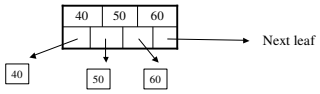
B+ Trees Basics

- Parameter d = the *degree*
- Each node has >= d and <= 2d keys (except root)



- Each leaf has >=d and <= 2d keys:



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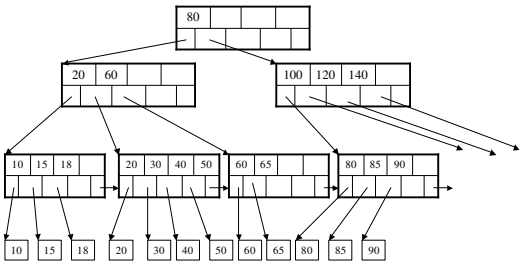
B+ Tree Example

d = 2



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B+ Tree Design

- How large d ?
- Example:
  - Key size = 4 bytes
  - Pointer size = 8 bytes
  - Block size = 4096 byes
- 2d x 4 + (2d+1) x 8 <= 4096
- d = 170

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Searching a B+ Tree

- Exact key values:
  - Start at the root
  - Proceed down, to the leaf

```
Select name
From people
Where age = 25
```

- Range queries:
  - As above
  - Then sequential traversal

```
Select name
From people
Where 20 <= age
  and  age <= 30
```

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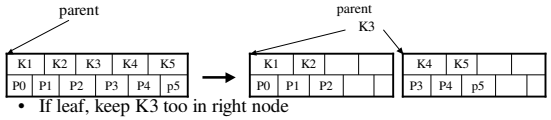
B+ Trees in Practice

- 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

Insertion in a B+ Tree

Insert (K, P)

- Find leaf where K belongs, insert
- If no overflow (2d keys or less), halt
- If overflow (2d+1 keys), split node, insert in parent:



- If leaf, keep K3 too in right node
- When root splits, new root has 1 key only

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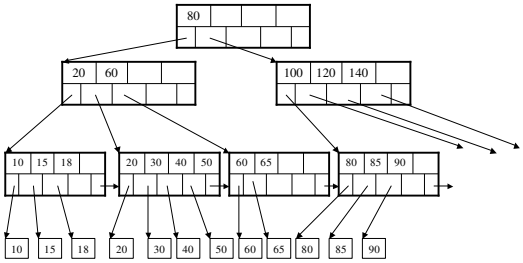
Insertion in a B+ Tree

Insert K=19



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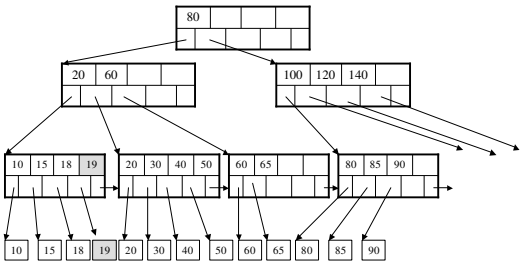
Insertion in a B+ Tree

After insertion



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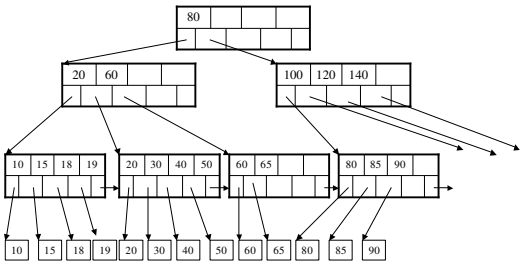
Insertion in a B+ Tree

Now insert 25



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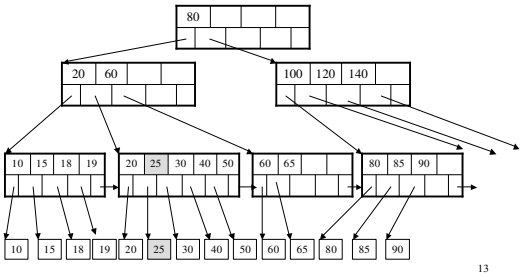
Insertion in a B+ Tree

After insertion



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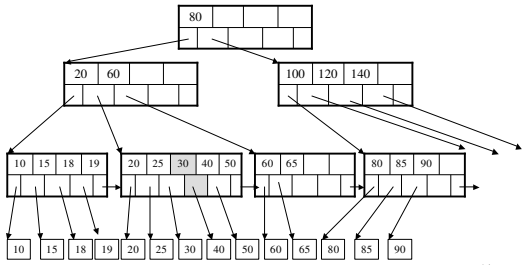
Insertion in a B+ Tree

But now have to split !



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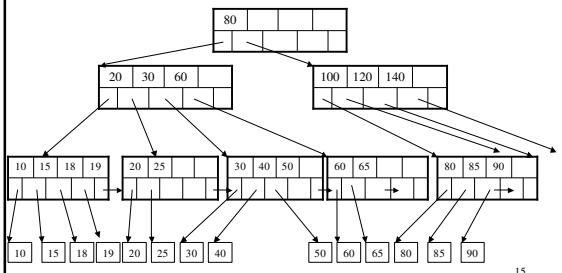
Insertion in a B+ Tree

After the split



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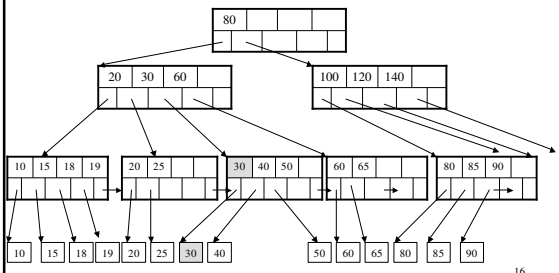
Deletion from a B+ Tree

Delete 30



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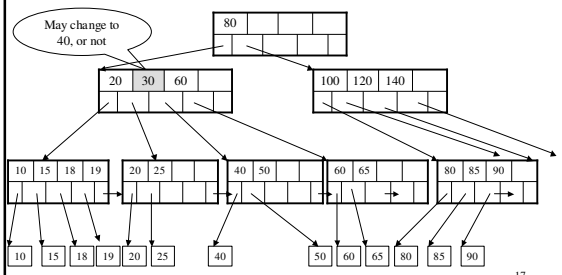
Deletion from a B+ Tree

After deleting 30



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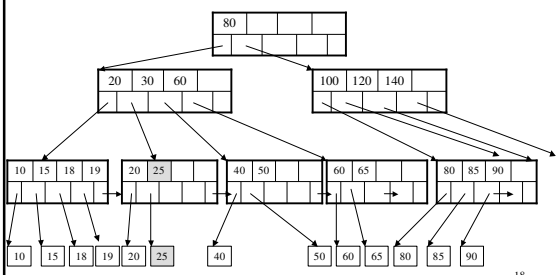
Deletion from a B+ Tree

Now delete 25



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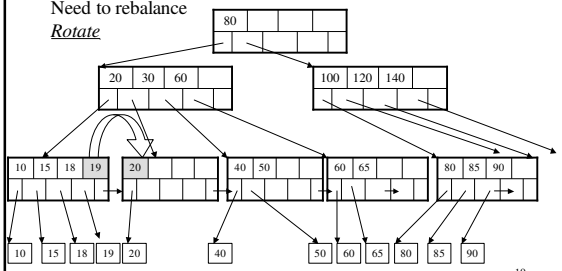
Deletion from a B+ Tree

After deleting 25
Need to rebalance
Rotate



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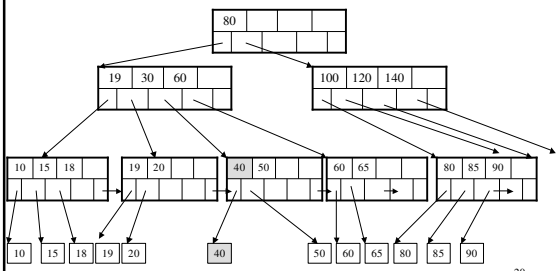
Deletion from a B+ Tree

Now delete 40



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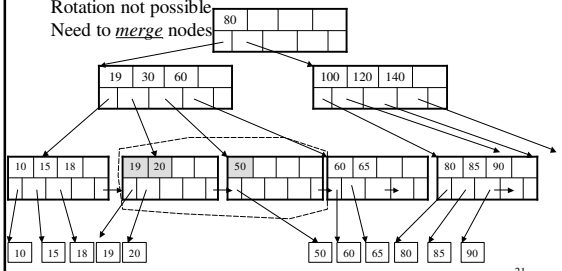
Deletion from a B+ Tree

After deleting 40
Rotation not possible
Need to *merge* nodes



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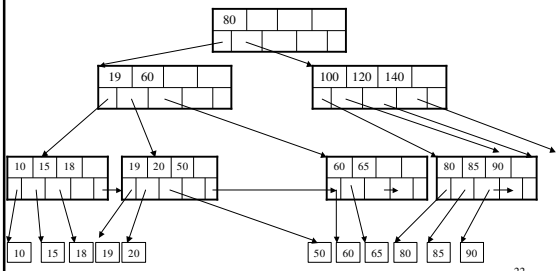
Deletion from a B+ Tree

Final tree



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