Indexing

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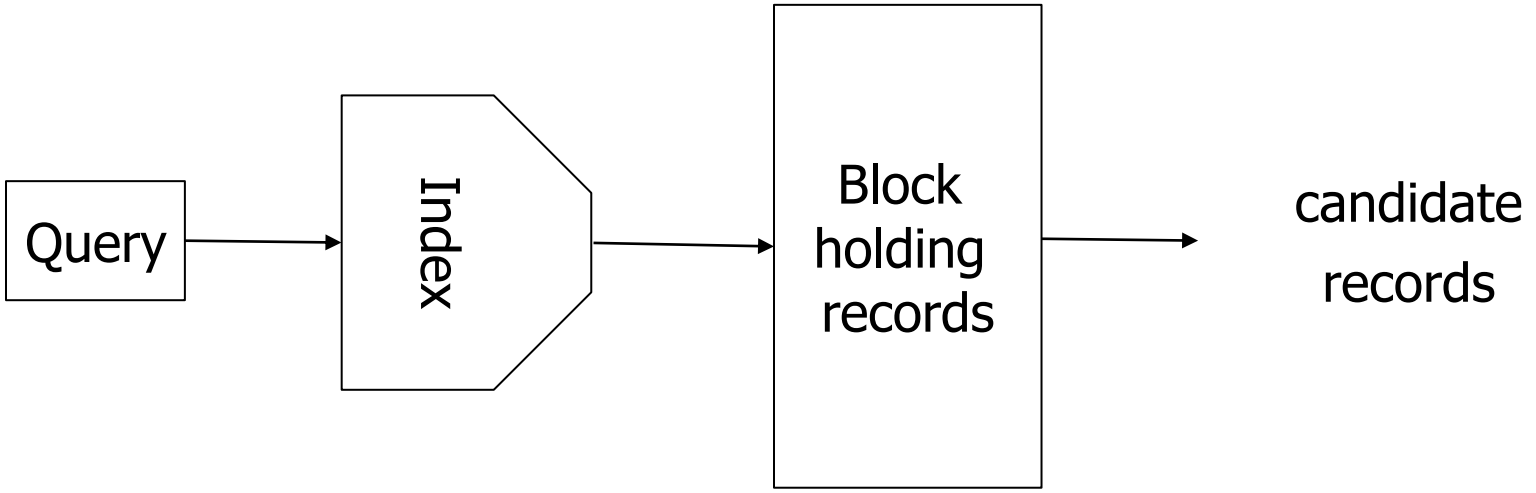
Indexing



Topics

- Conventional indexes
- B-trees
- Hashing schemes

Sequential File

10	
20	

30	
40	

50	
60	

70	
80	

90	
100	

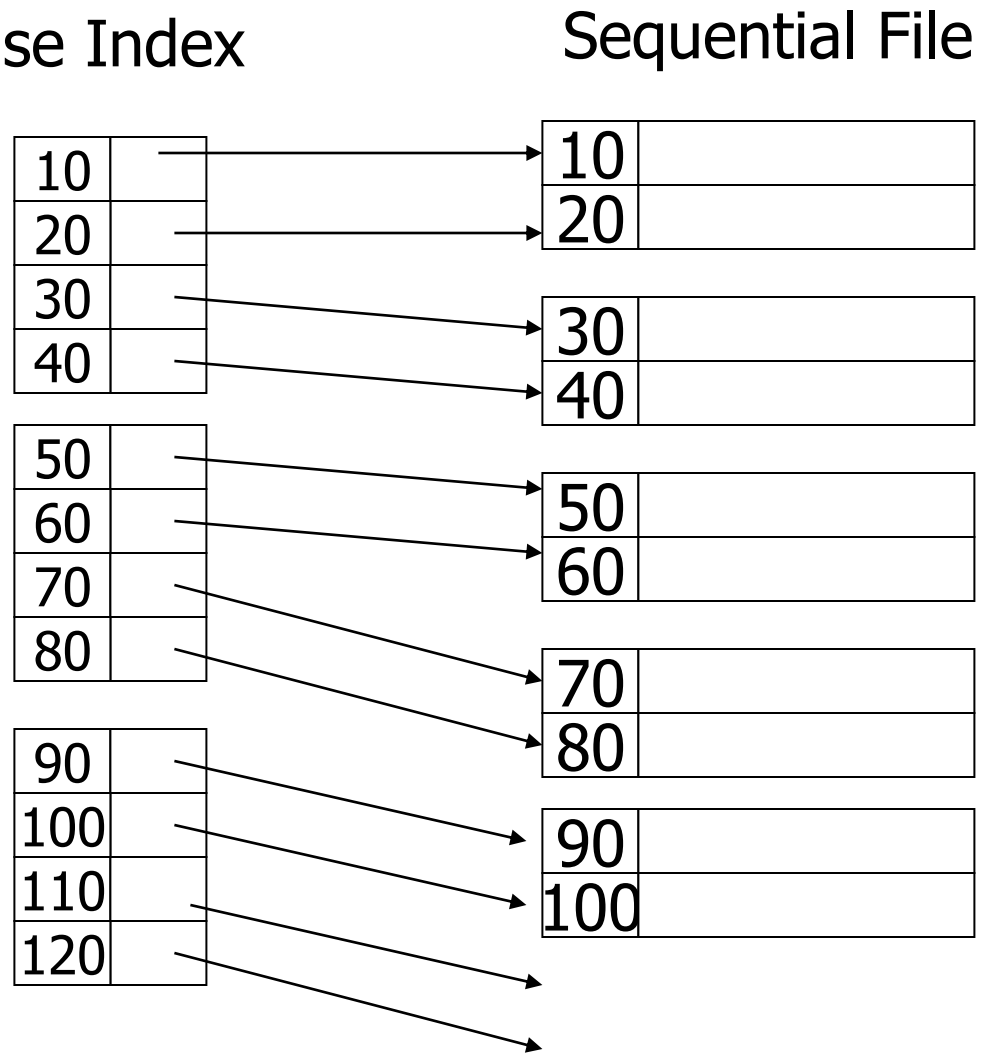
Dense Index = a pointer per key

How to search for a key= 30 ?

How to search for a key= 25 ?

Can we use a dense index on a non-sequential file ?

Why querying a dense index is more efficient than querying the sequential file ?

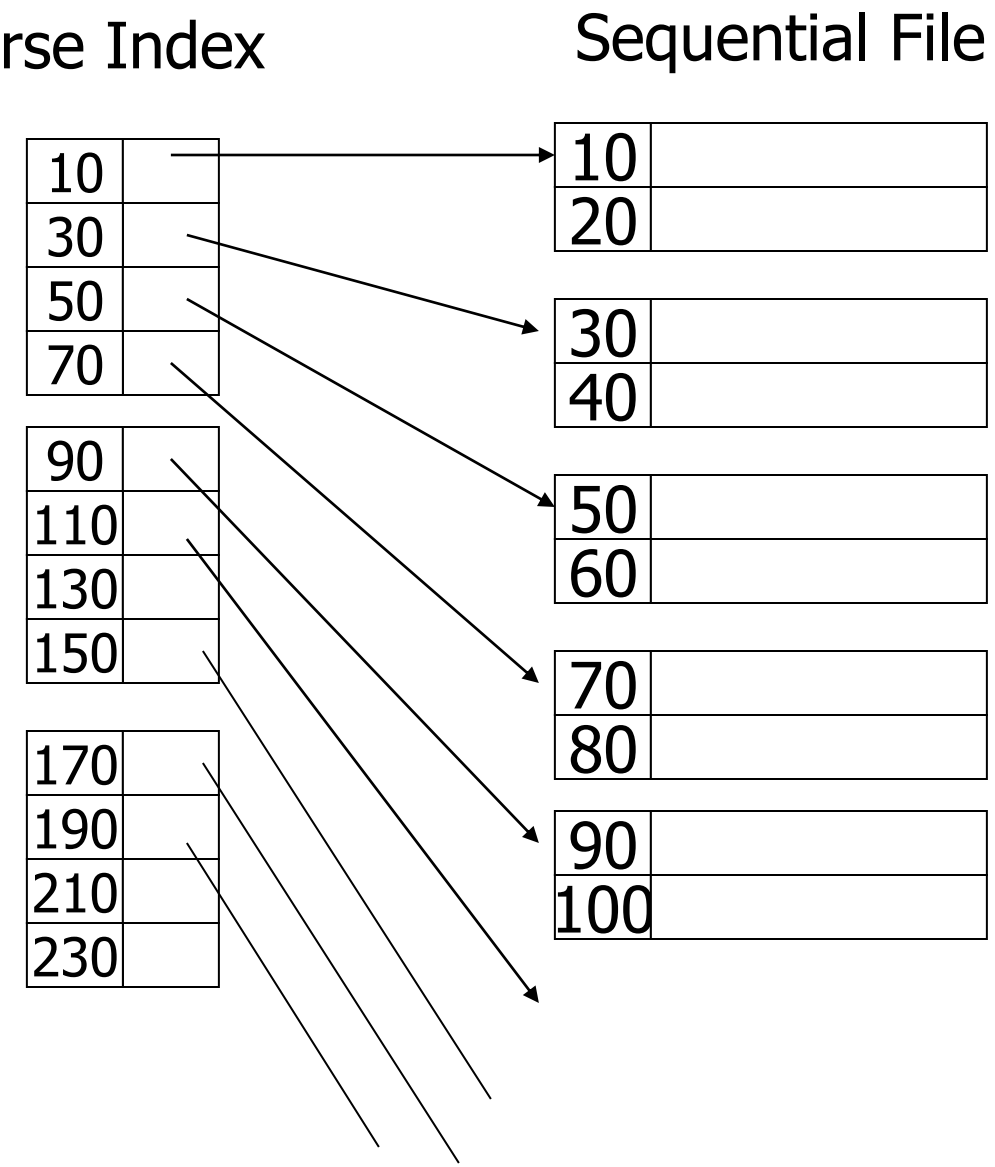


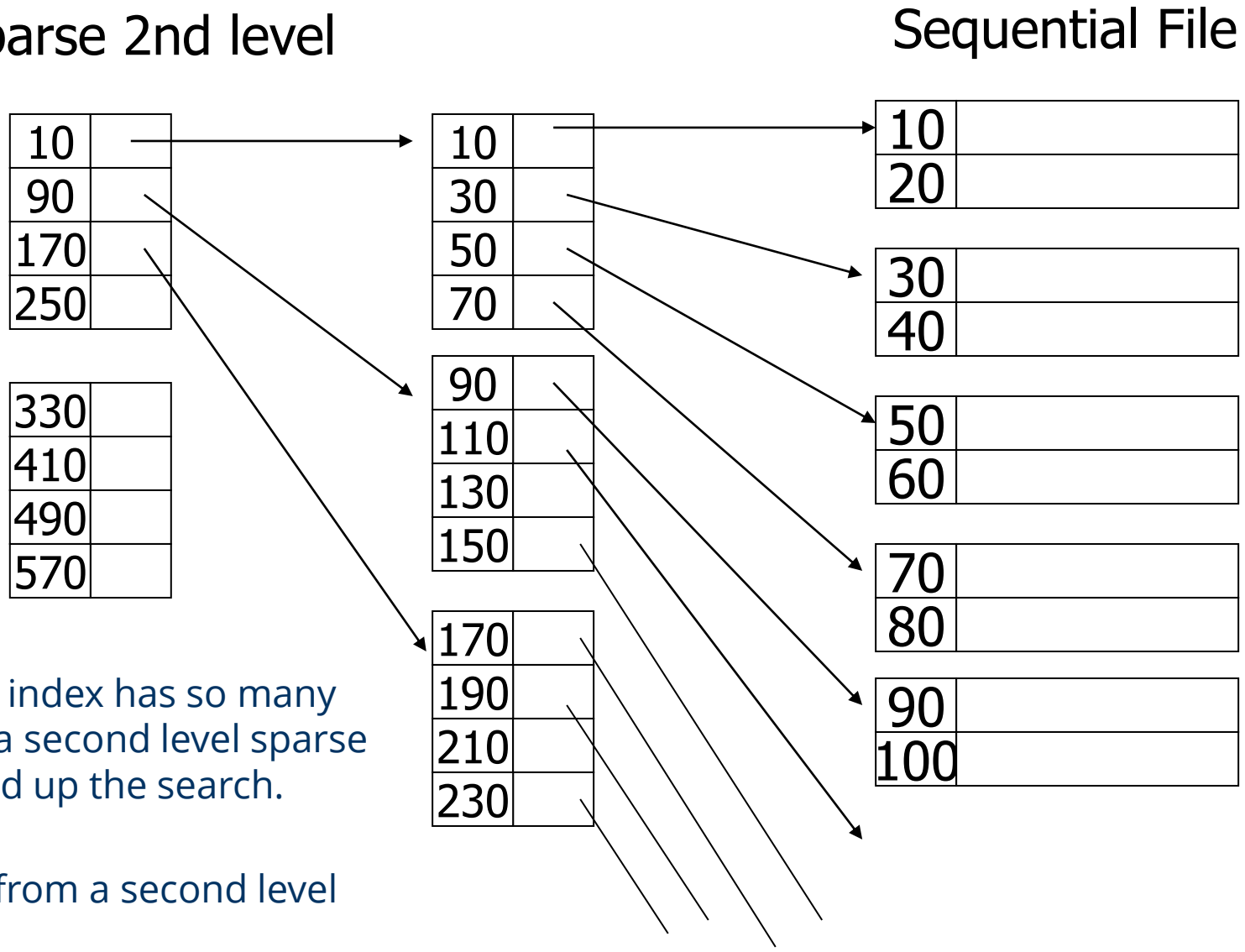
Sparse index = a pointer per block

How to search for a key= 30 ?

How to search for a key= 25 ?

Can we use a sparse index on a non-sequential file ?





If the first level index has so many pages, adding a second level sparse index can speed up the search.

Do we benefit from a second level dense index ?

Sparse vs. Dense Tradeoff

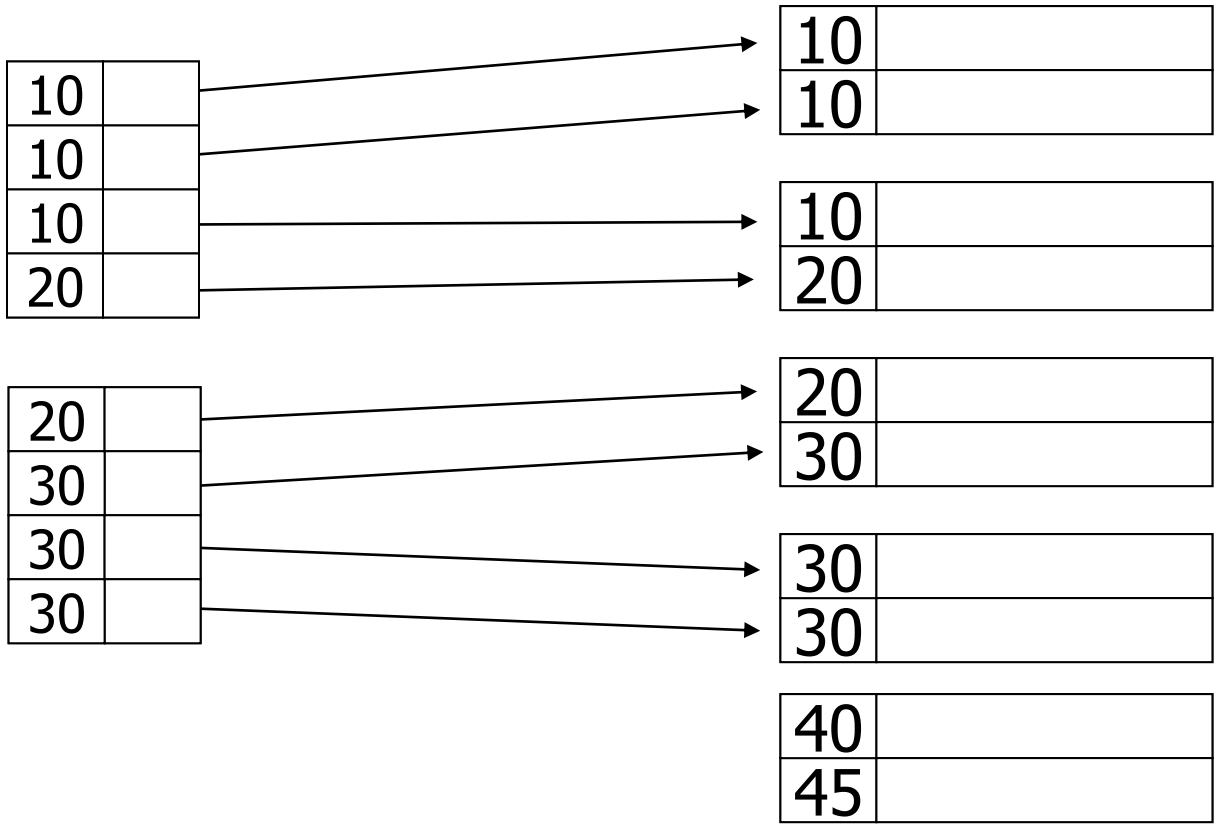
- Sparse: Less index space per record
  can keep more of index in memory
- Dense: Can tell if any record exists
  without accessing file

Duplicate keys

Dense index, one way to implement?

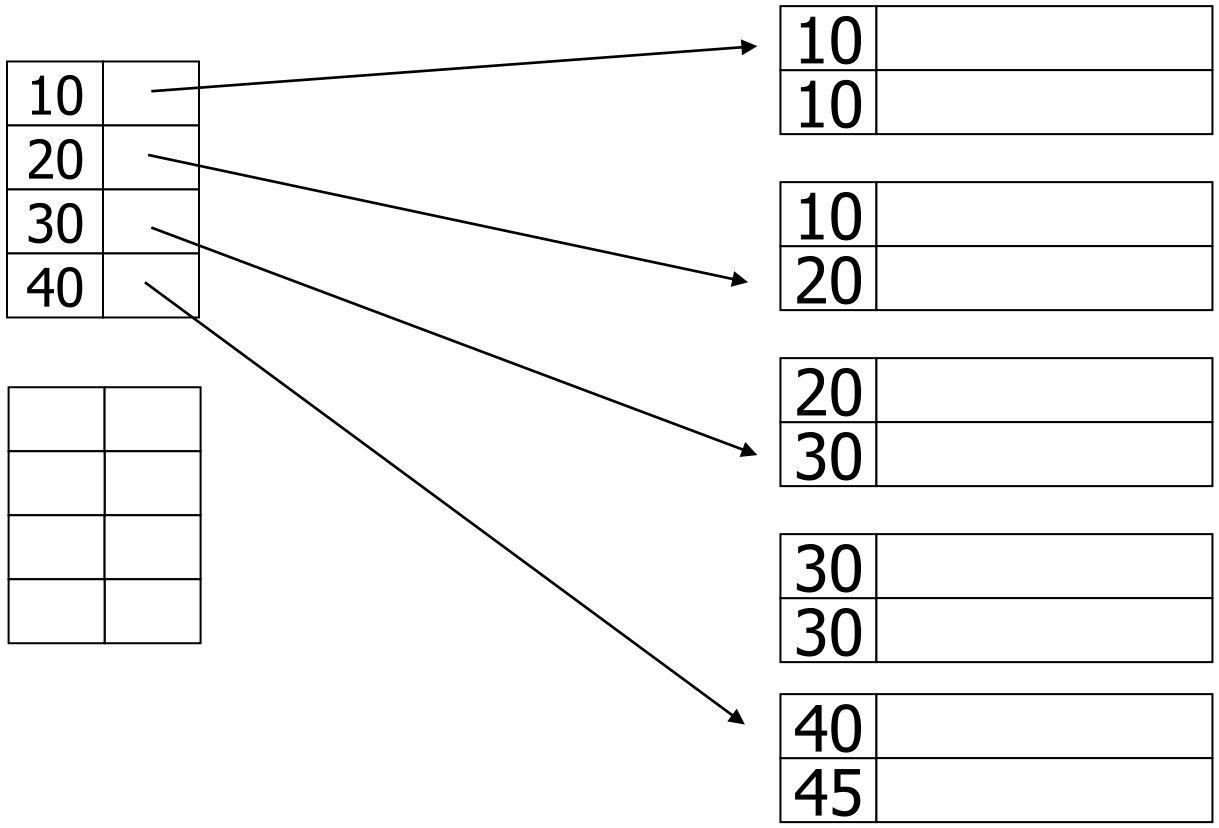
Dense index.

Can We do better ?



Duplicate keys

Dense index, better way?

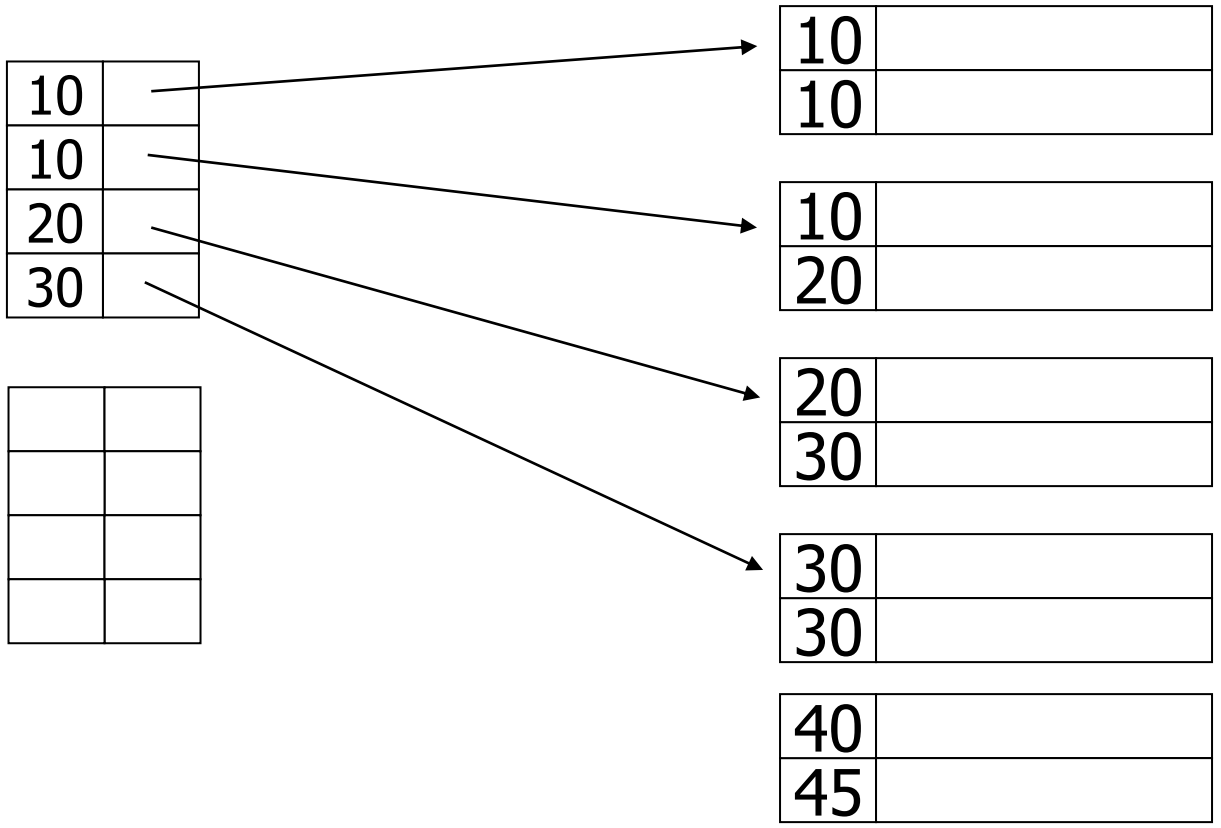


Duplicate keys

Sparse index, one way?

Sparse index - place key from block

How to search for 30 ?



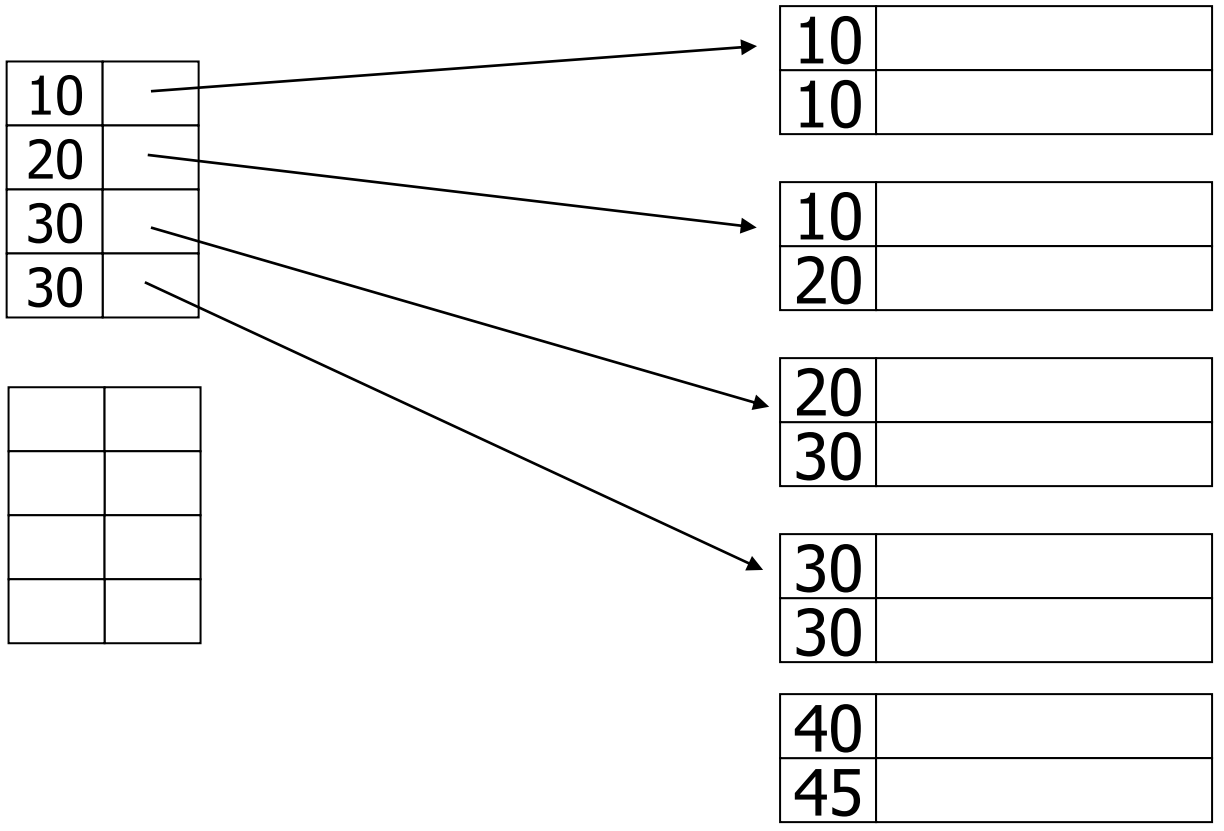
Duplicate keys

Sparse index, another way?

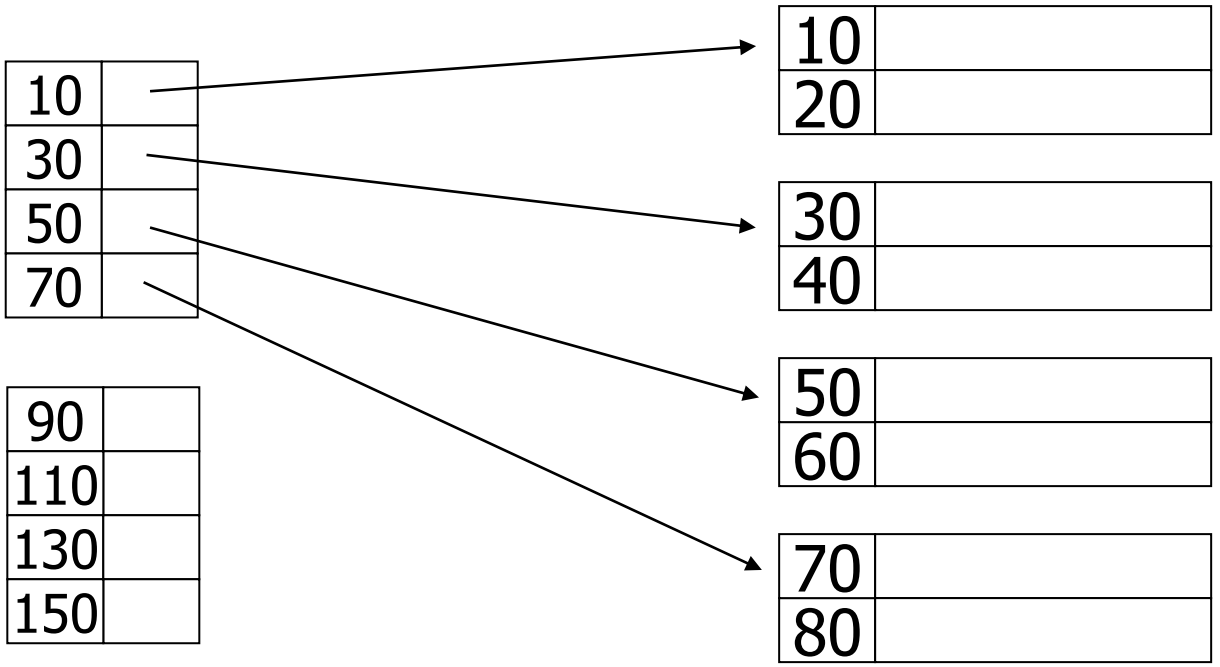
Sparse index - place first new key from block

How to search for 30 ?

How to search for 35 ?

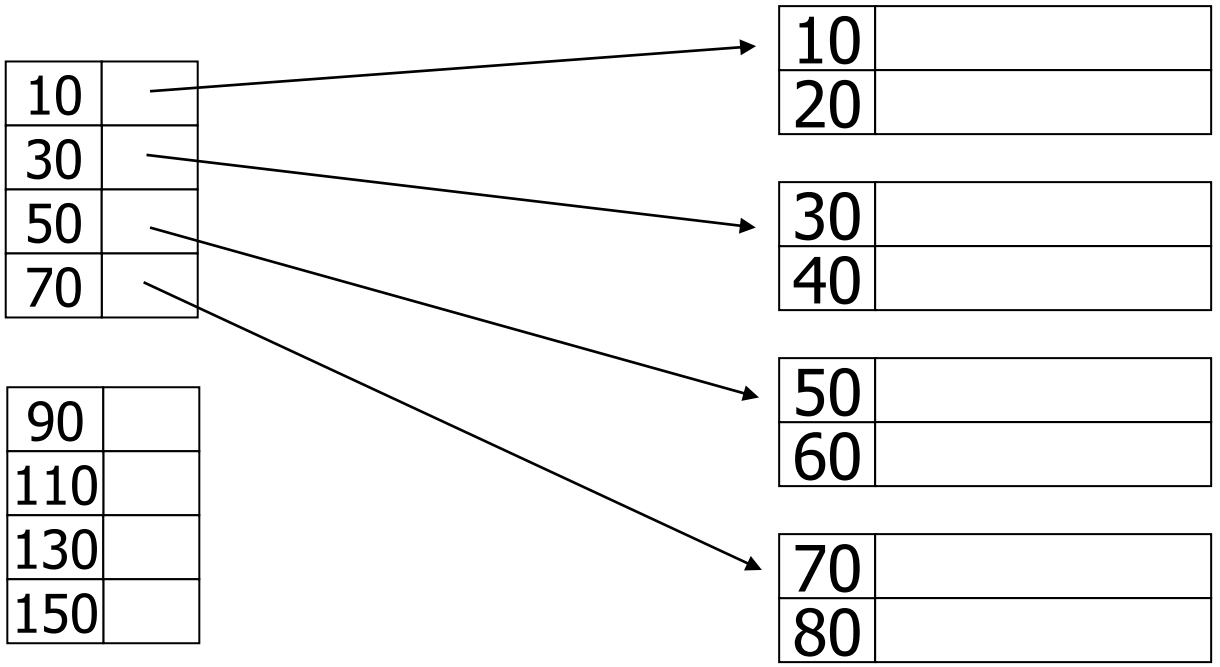


Deletion from sparse index



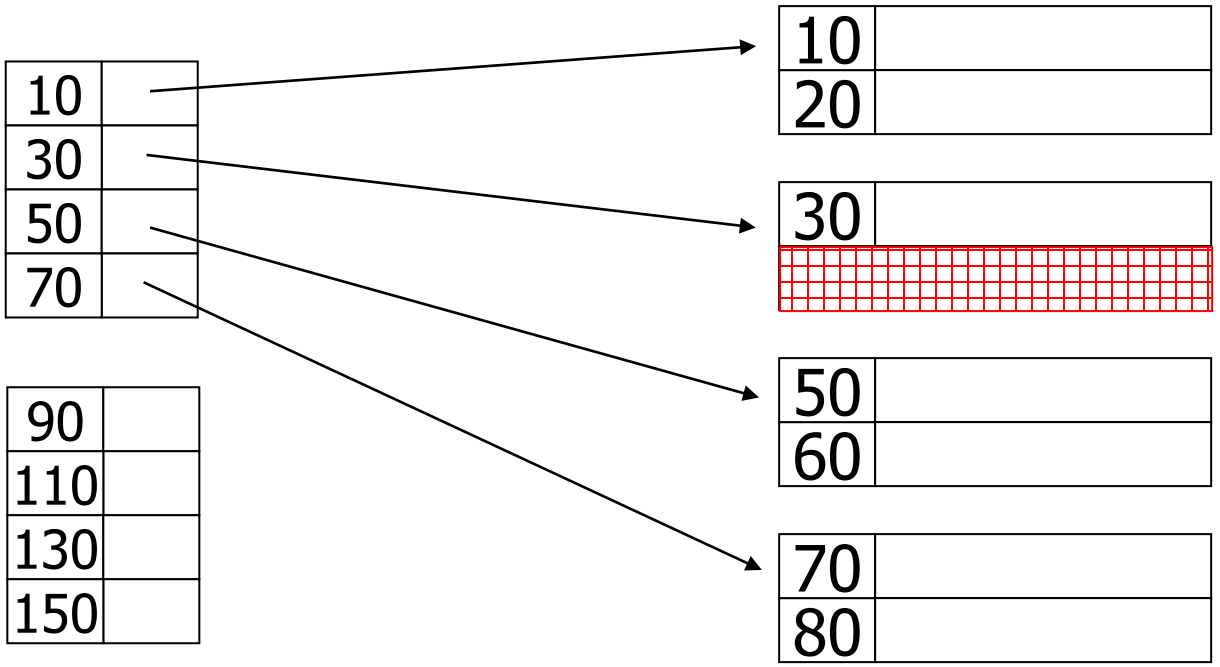
Deletion from sparse index

– delete record 40



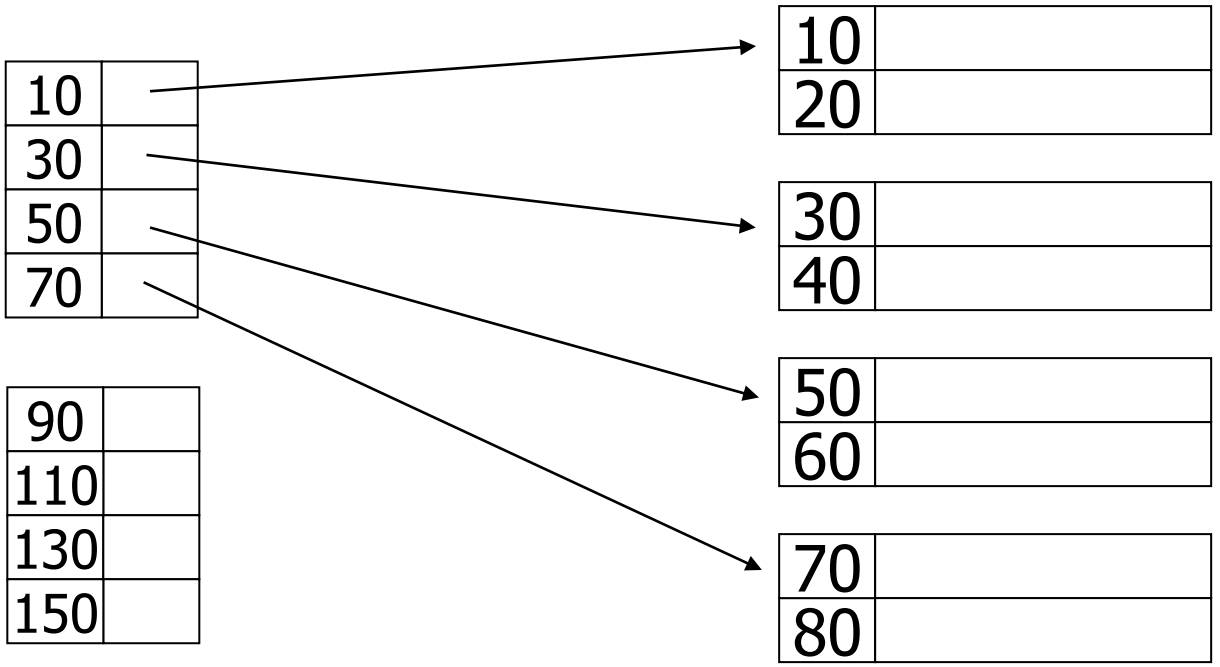
Deletion from sparse index

– delete record 40



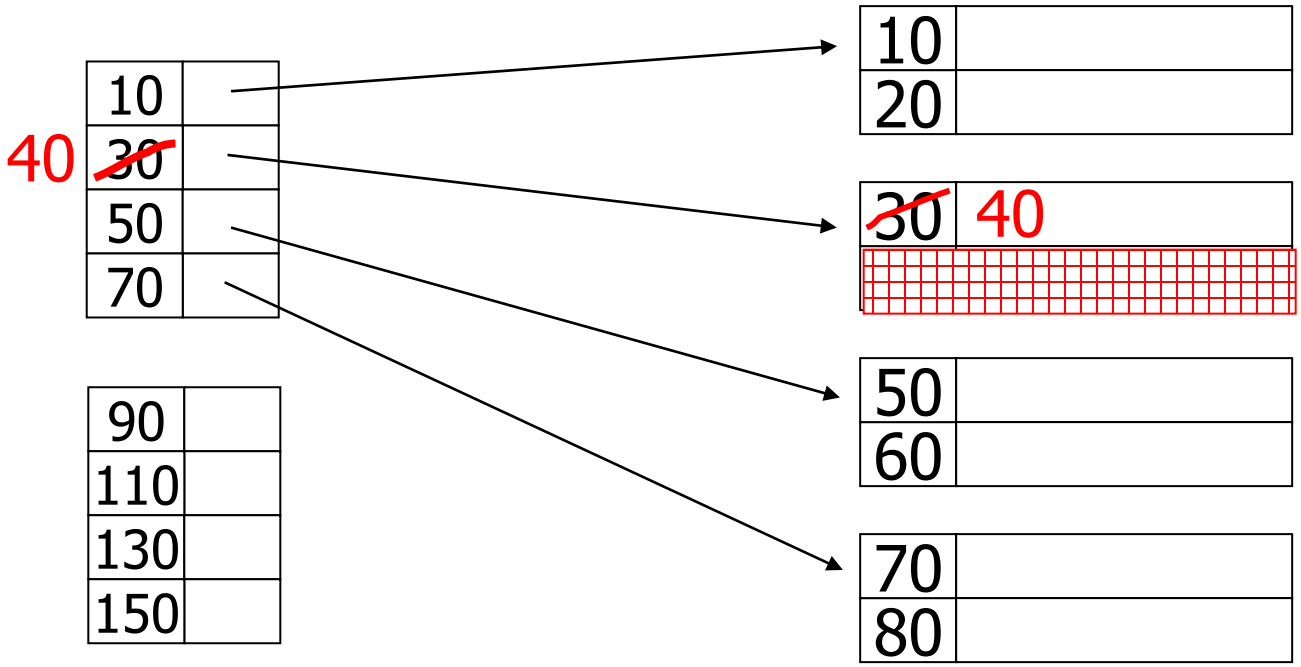
Deletion from sparse index

– delete record 30



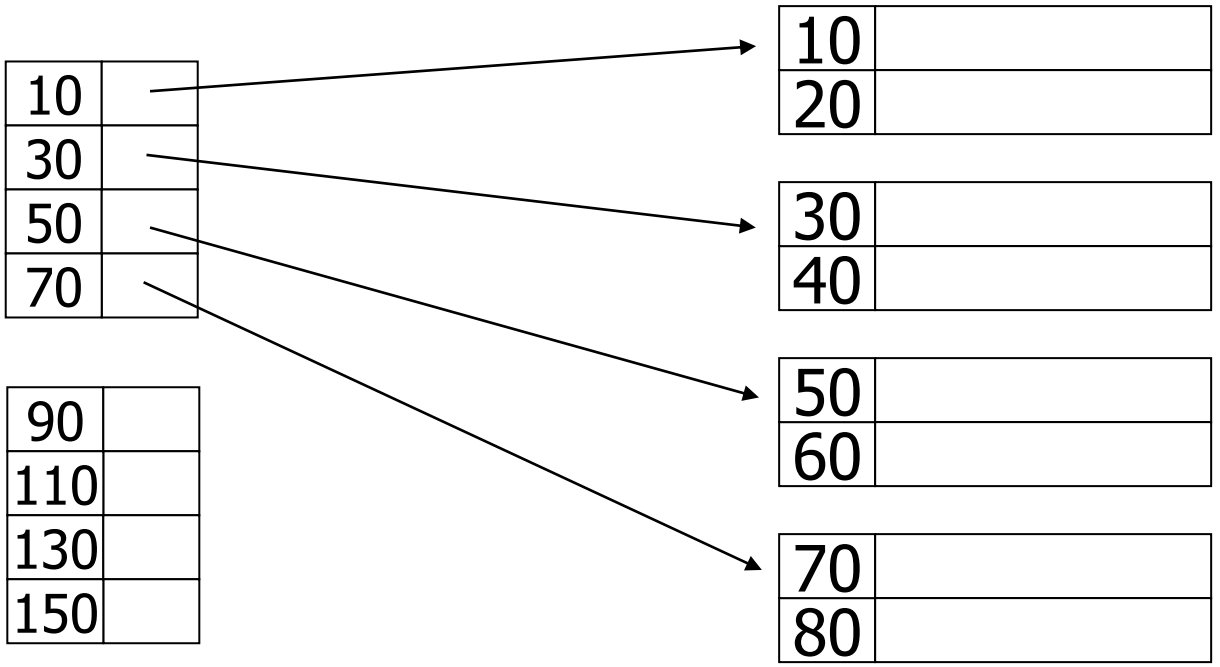
Deletion from sparse index

– delete record 30



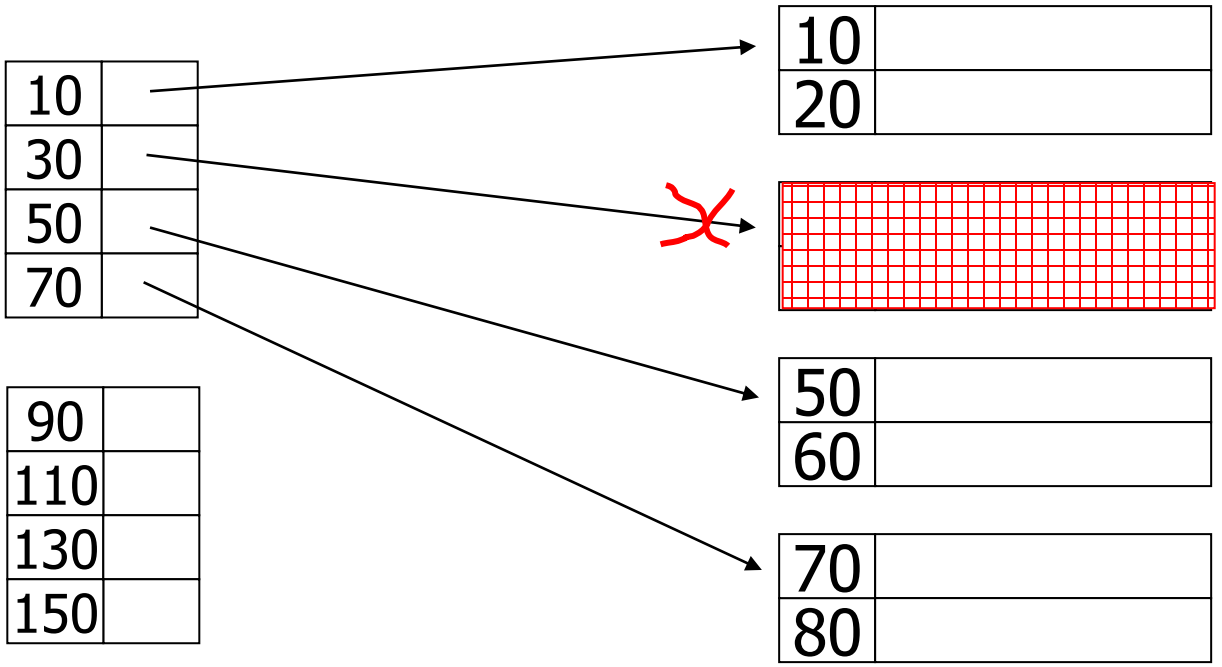
Deletion from sparse index

– delete records 30 & 40



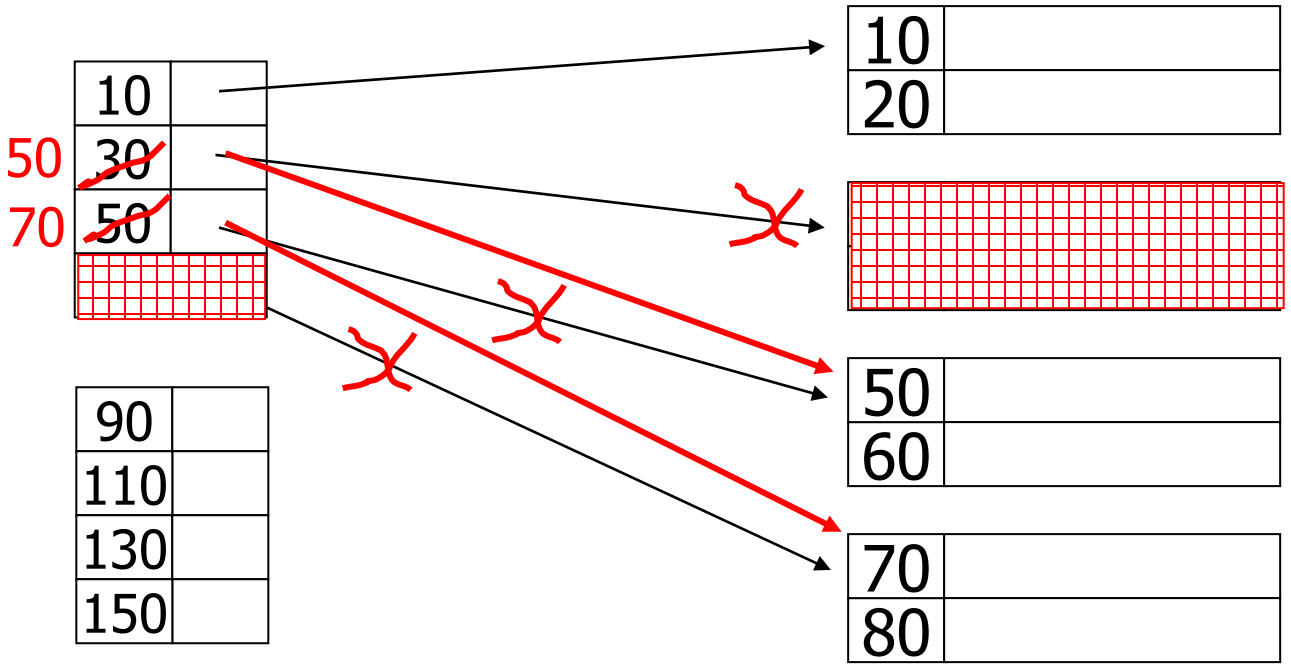
Deletion from sparse index

– delete records 30 & 40

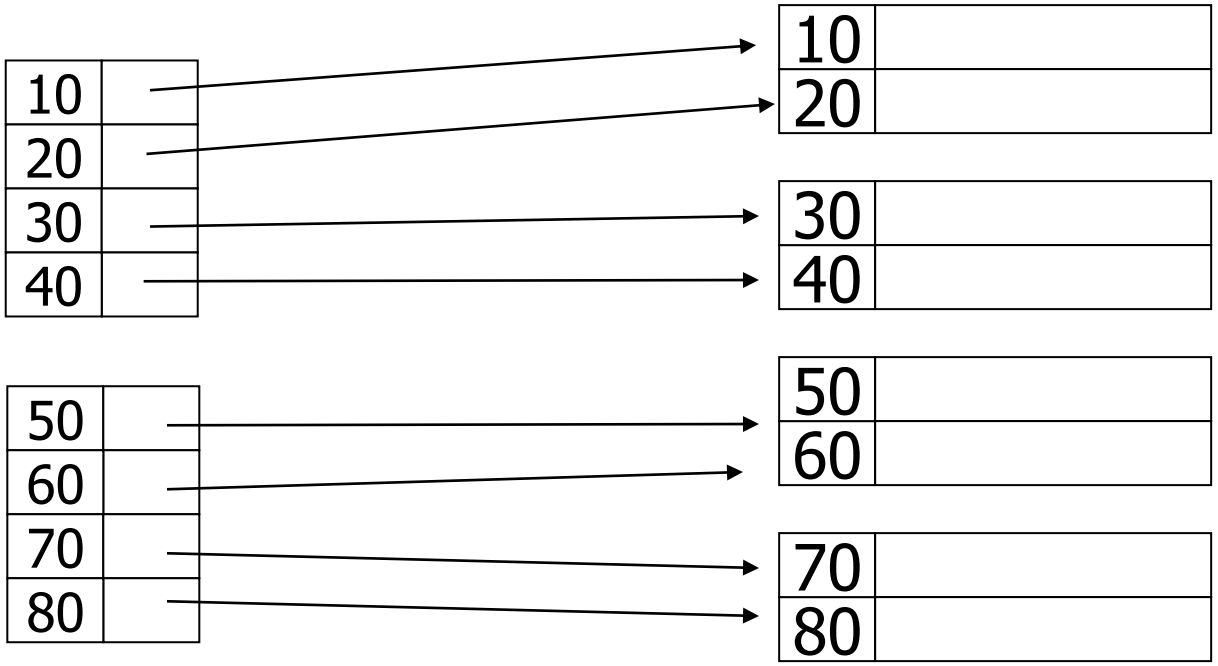


Deletion from sparse index

– delete records 30 & 40

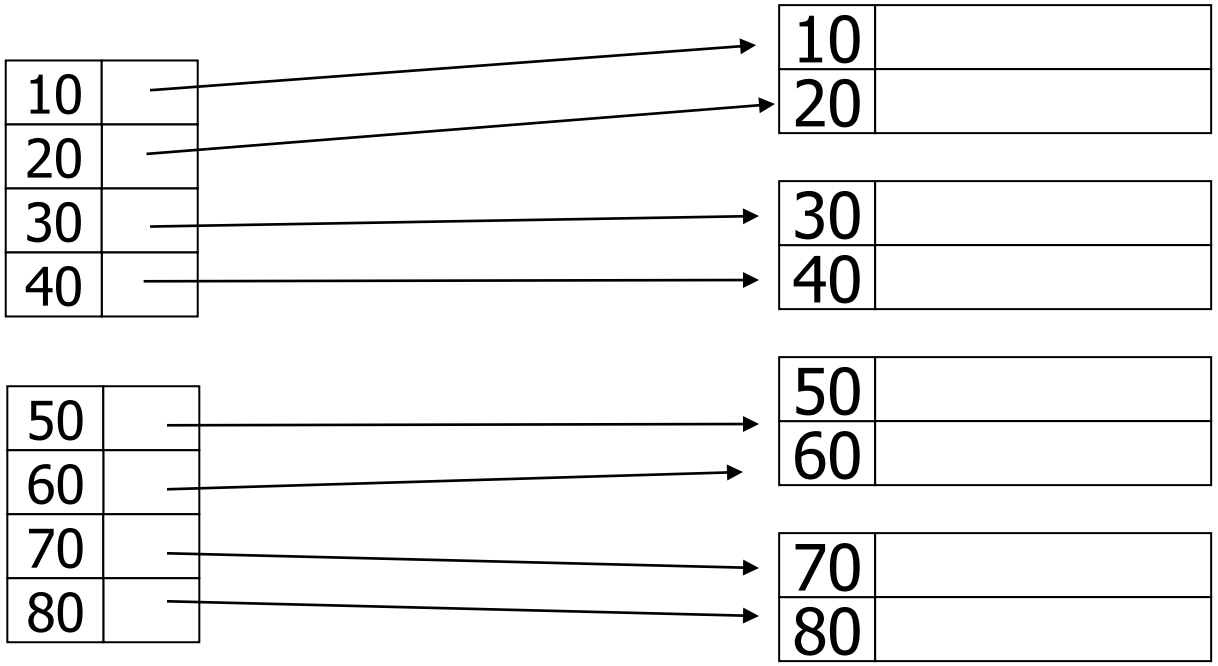


Deletion from dense index



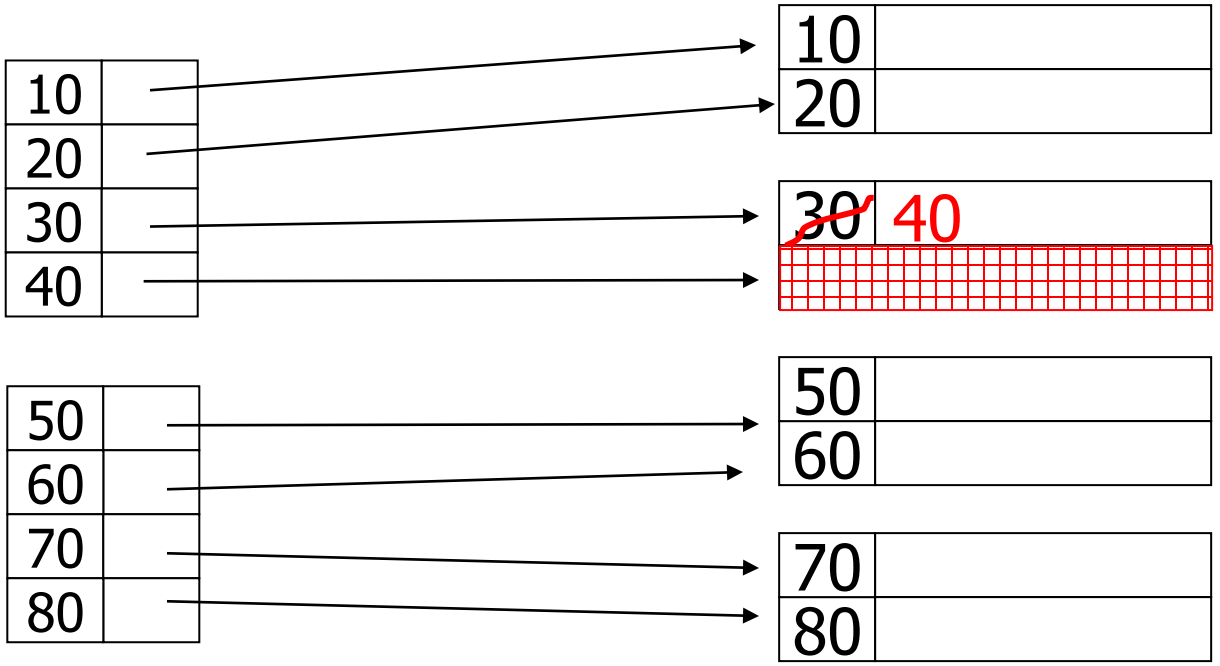
Deletion from dense index

– delete record 30



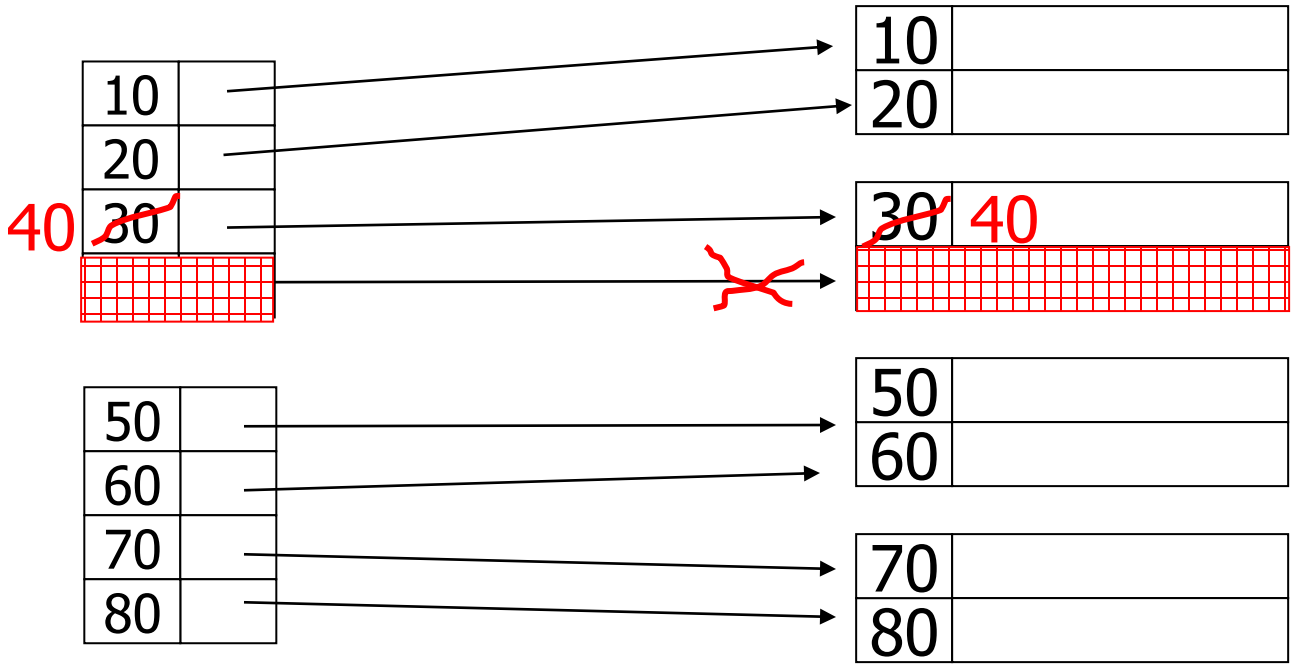
Deletion from dense index

– delete record 30

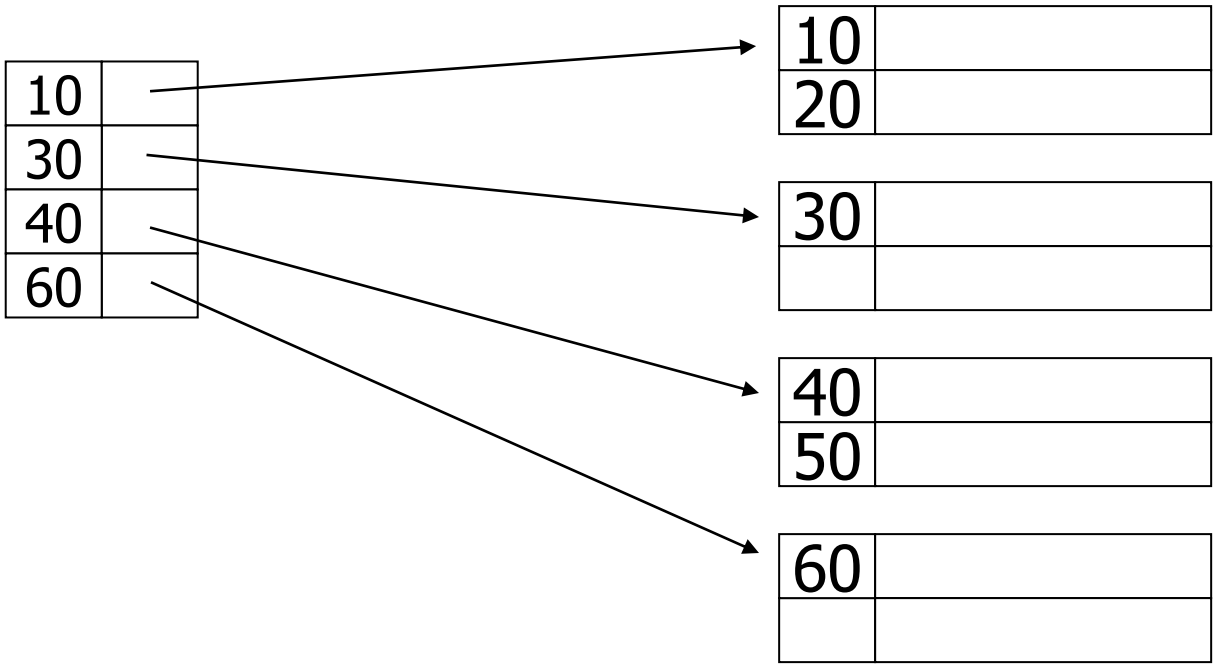


Deletion from dense index

– delete record 30

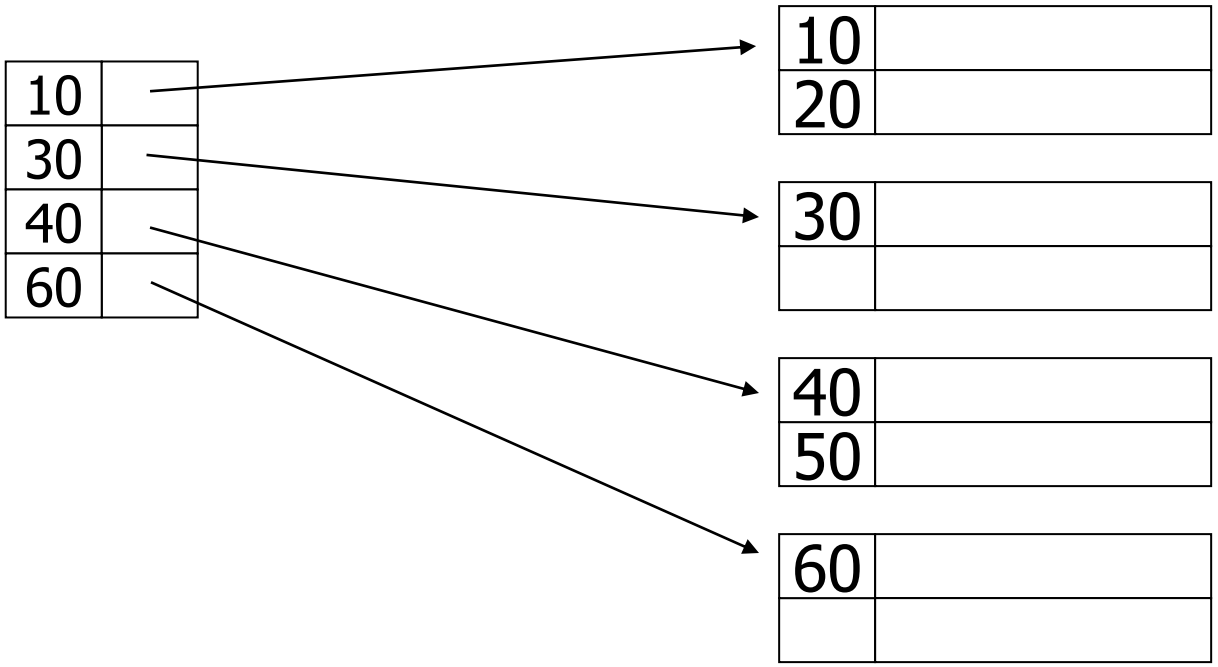


Insertion, sparse index case



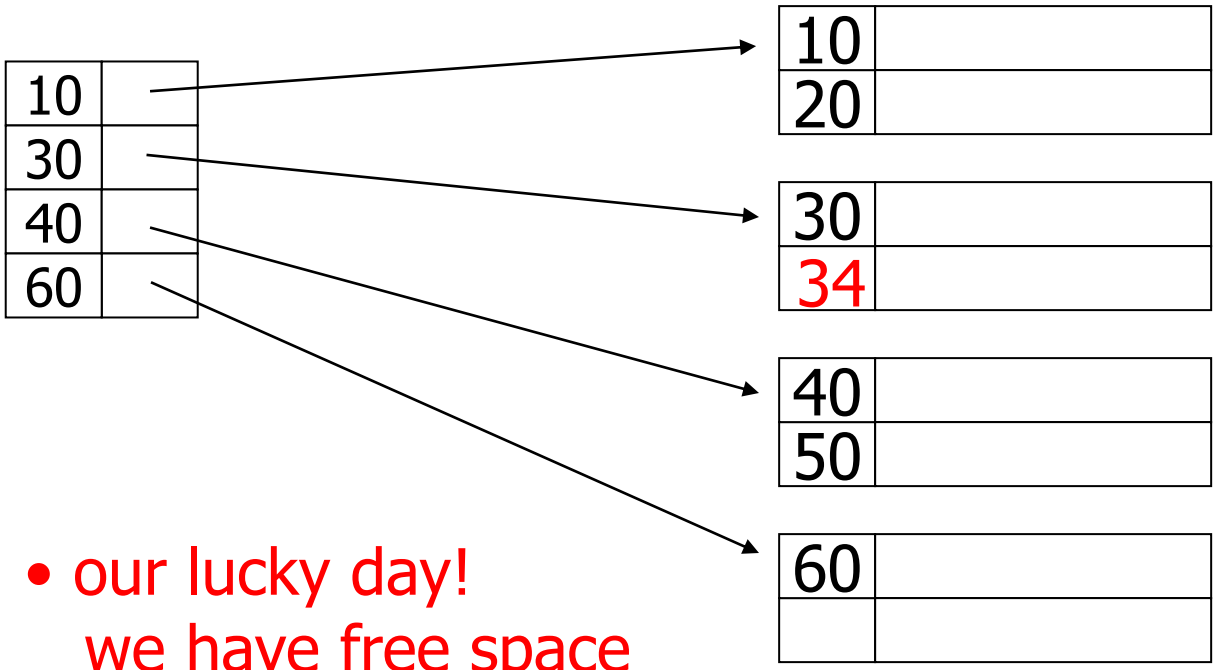
Insertion, sparse index case

– insert record 34



Insertion, sparse index case

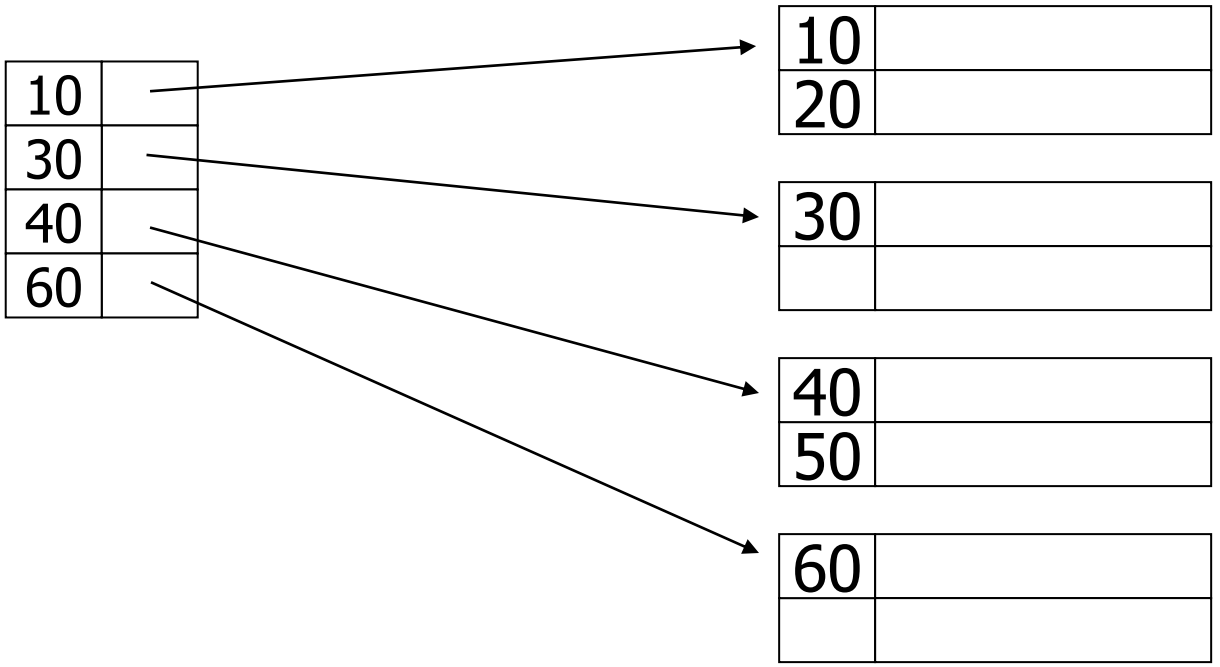
– insert record 34



- our lucky day!
  we have free space
  where we need it!

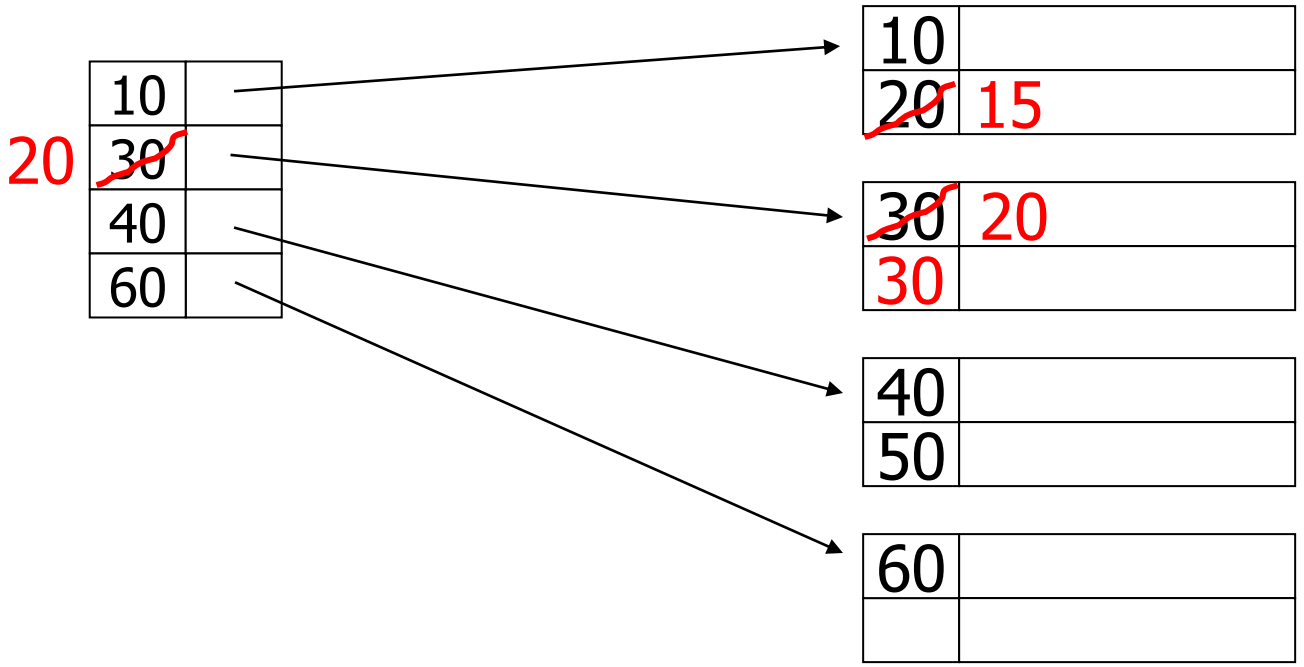
Insertion, sparse index case

– insert record 15



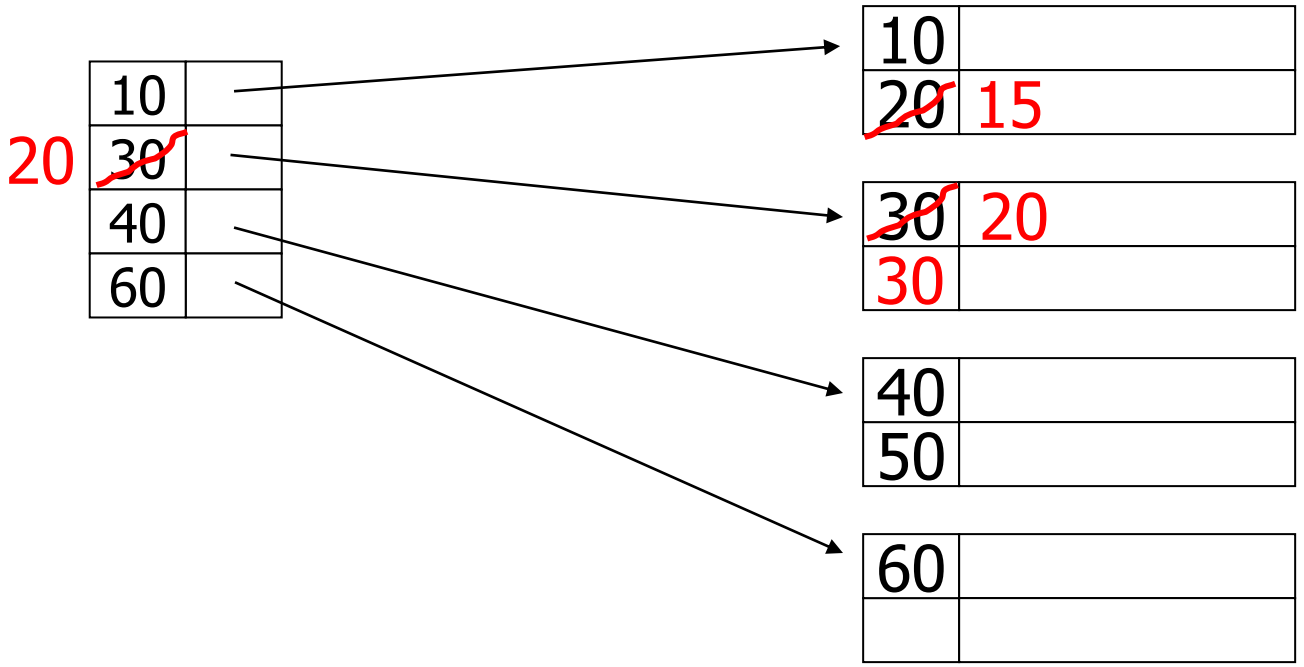
Insertion, sparse index case

– insert record 15



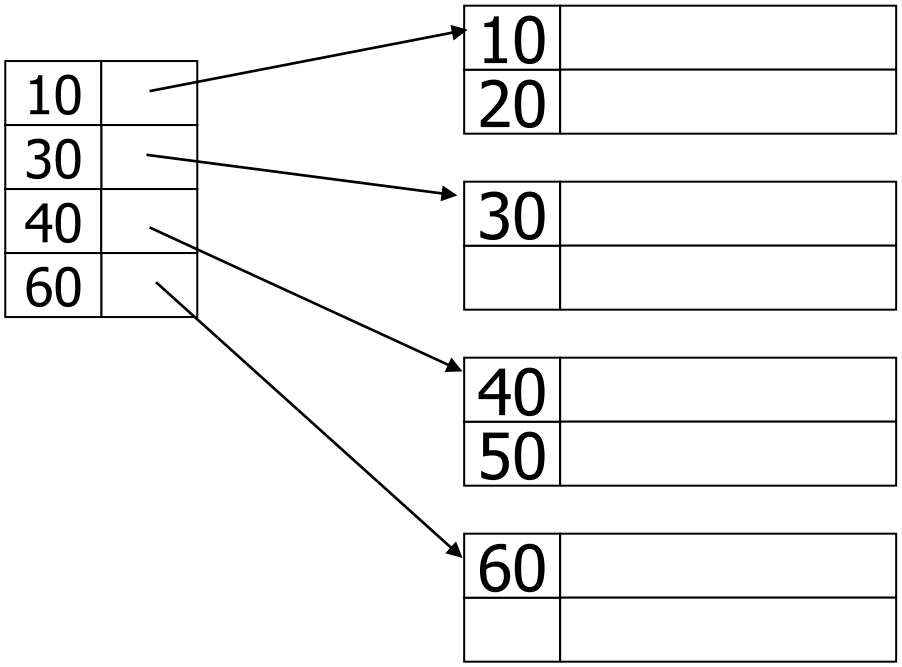
Insertion, sparse index case

– insert record 15



Insertion, sparse index case

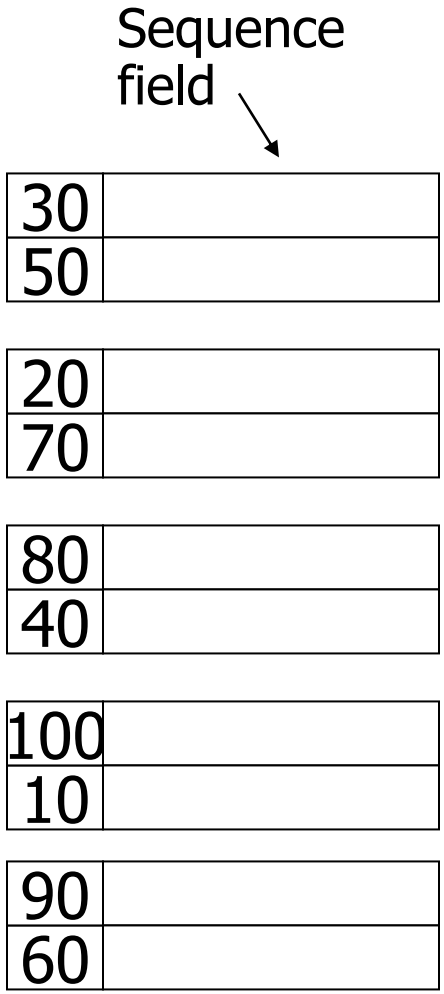
– insert record 25



Insertion, dense index case

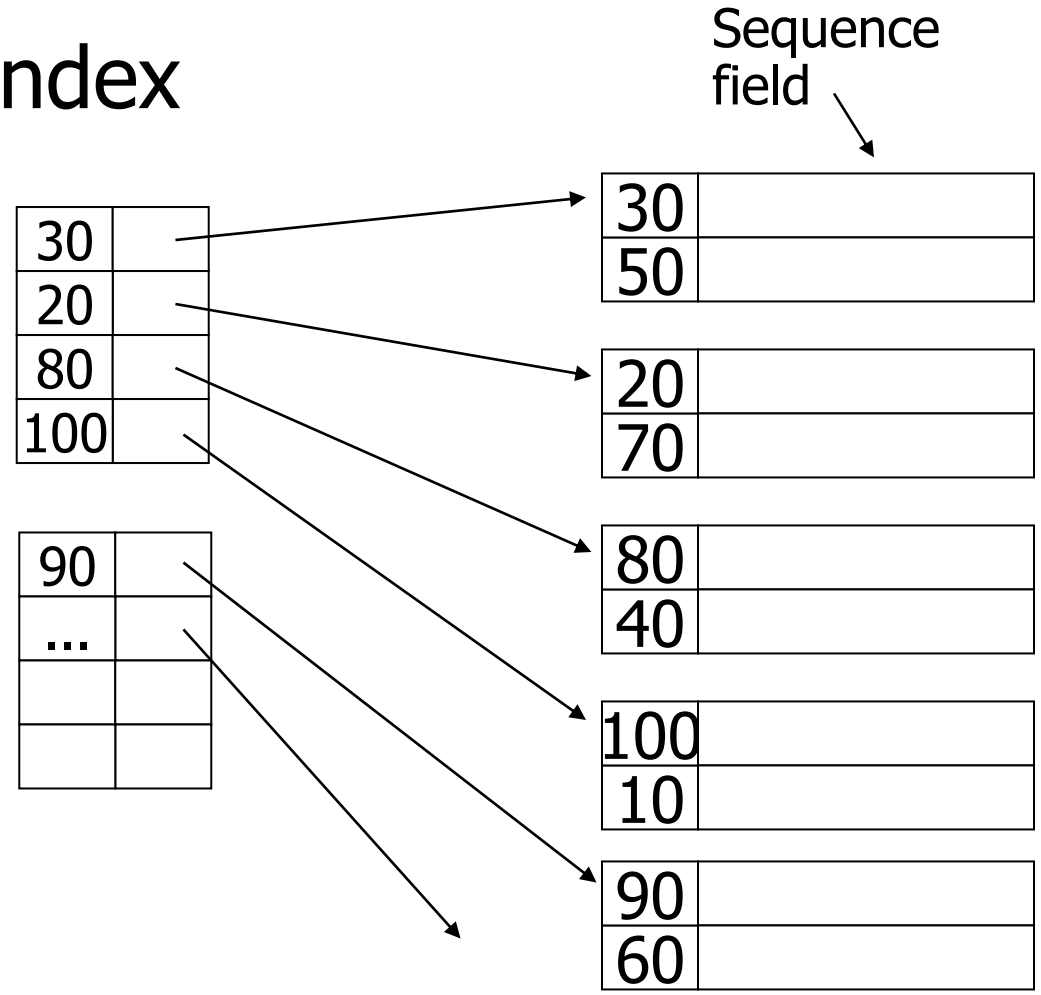
- Similar
- Often more expensive . . .

Secondary indexes



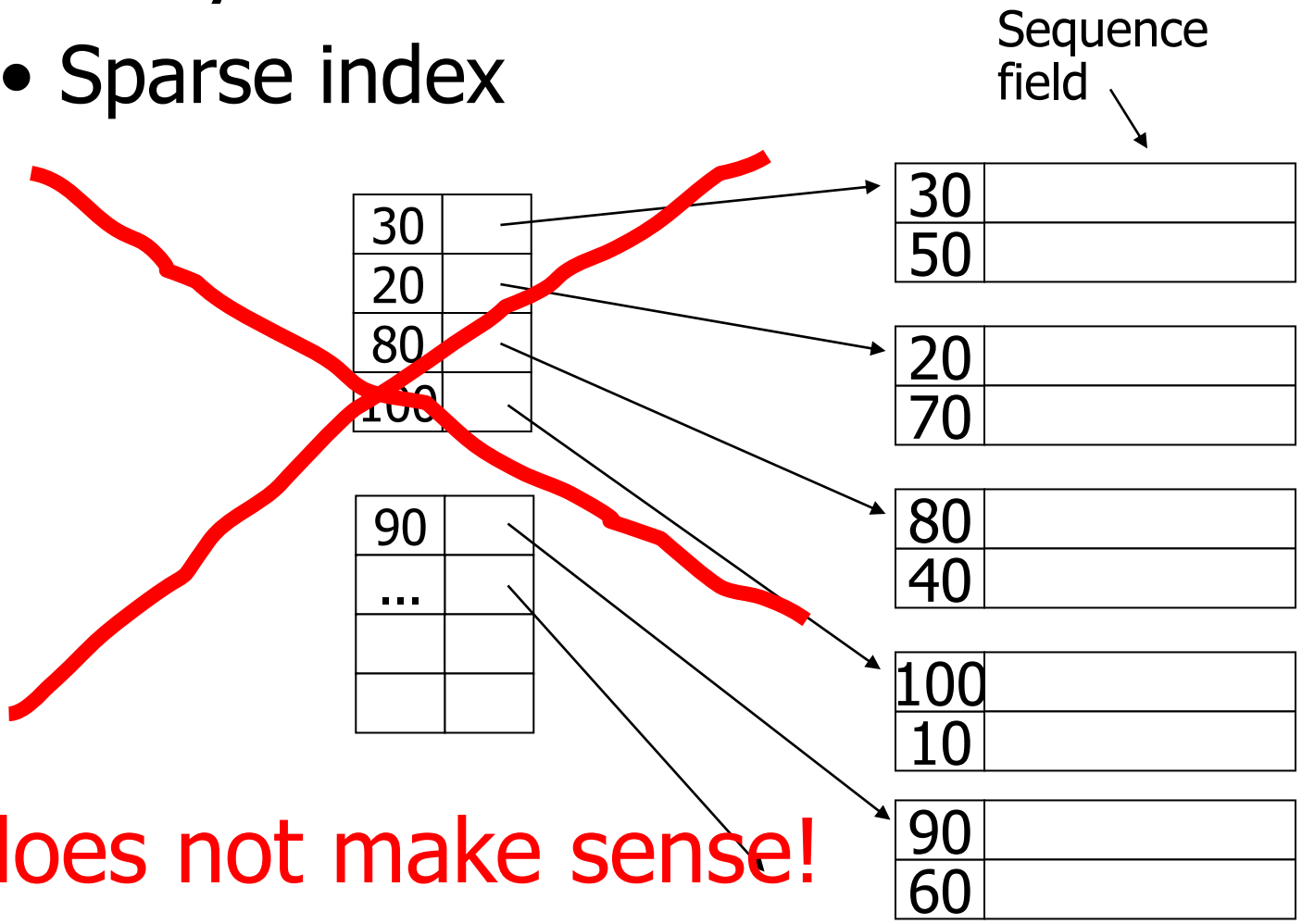
Secondary indexes

- Sparse index



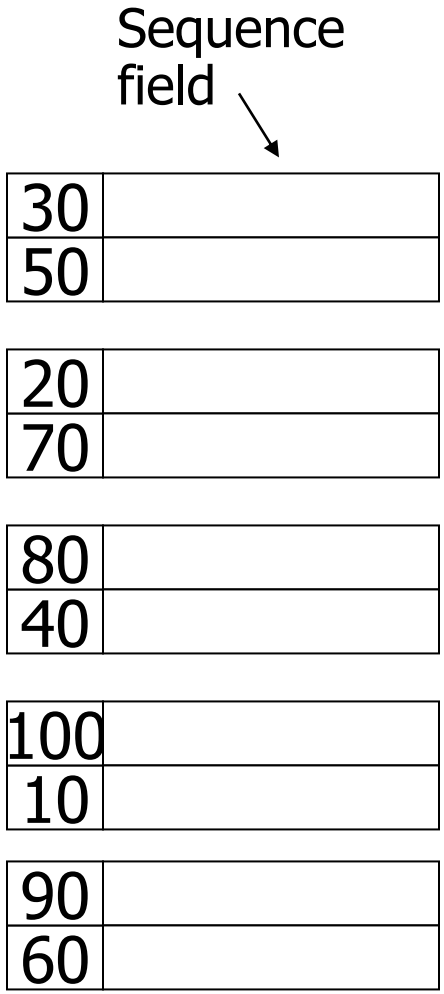
Secondary indexes

- Sparse index



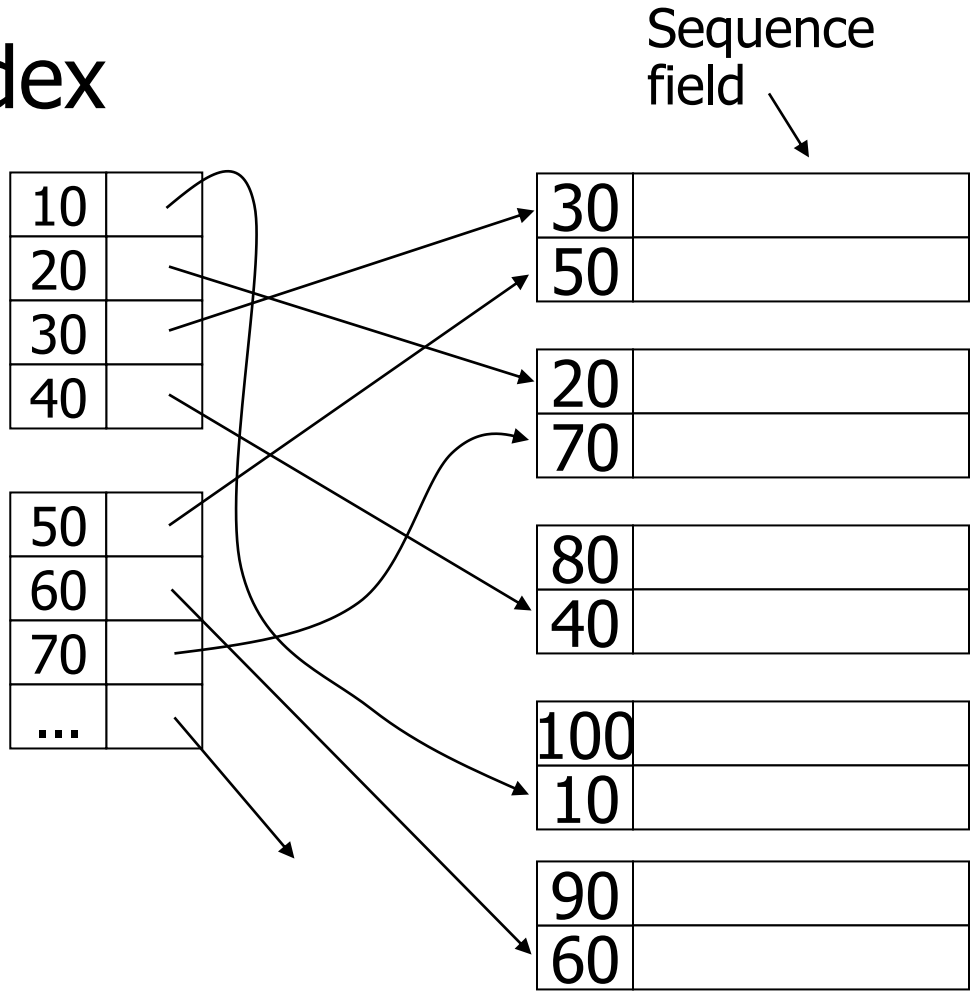
Secondary indexes

- Dense index



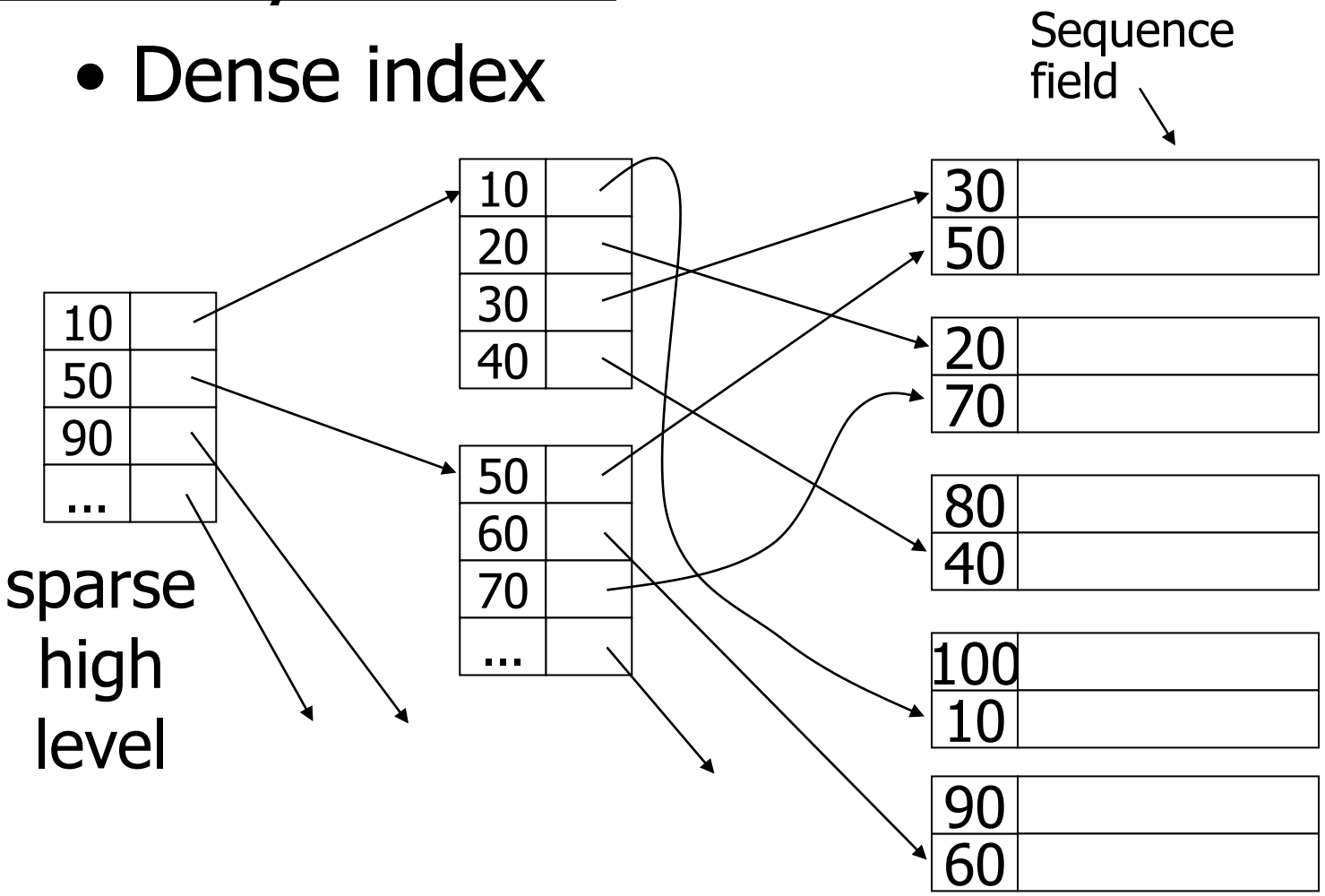
Secondary indexes

- Dense index



Secondary indexes

- Dense index



With secondary indexes:

- Lowest level is dense
- Other levels are sparse

Duplicate values & secondary indexes

20	
10	

20	
40	

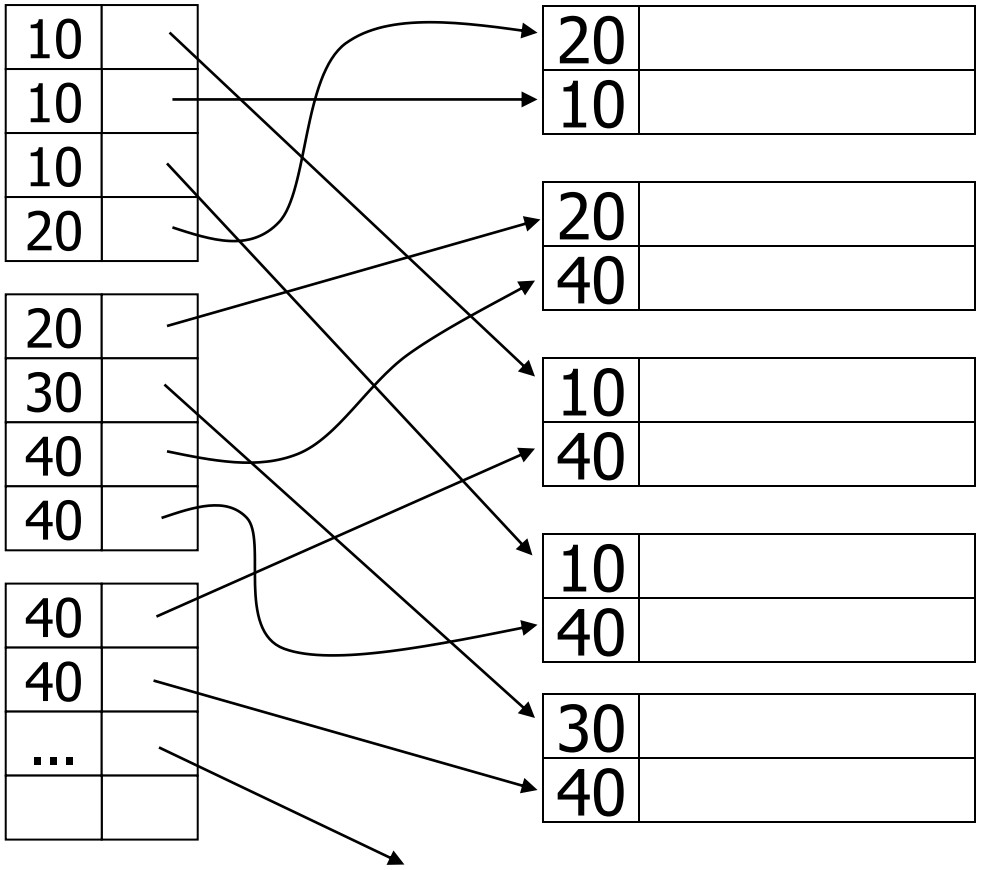
10	
40	

10	
40	

30	
40	

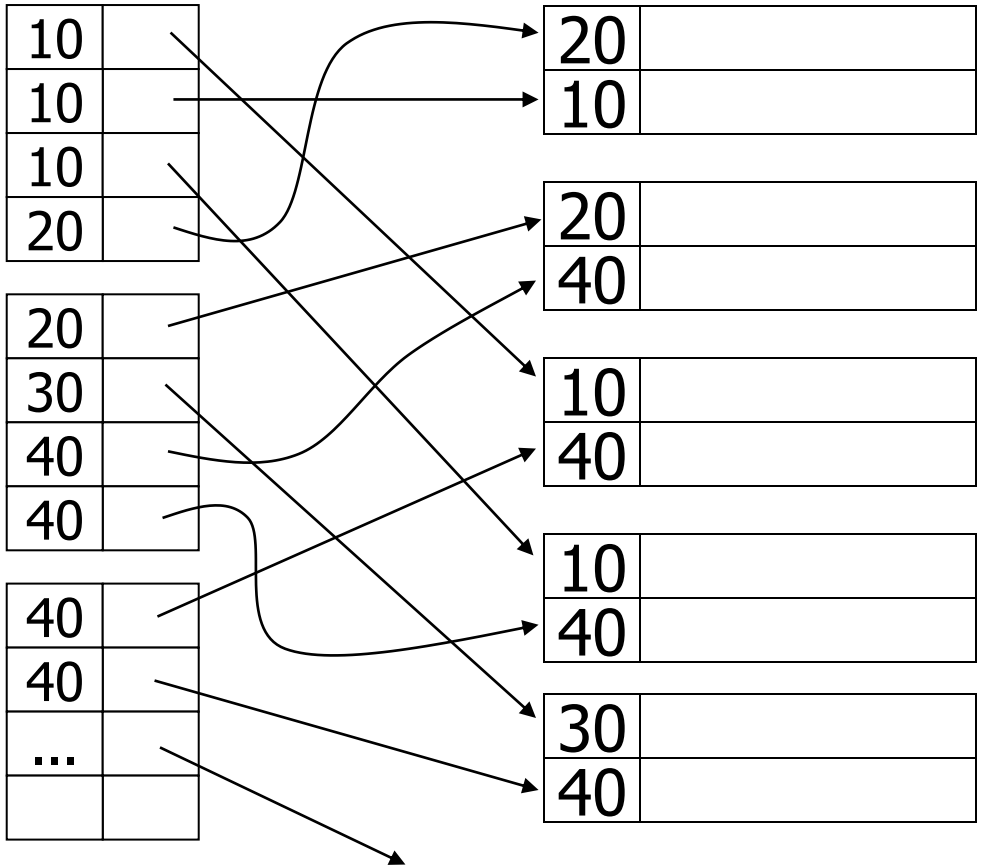
Duplicate values & secondary indexes

one option...



Duplicate values & secondary indexes

one option...



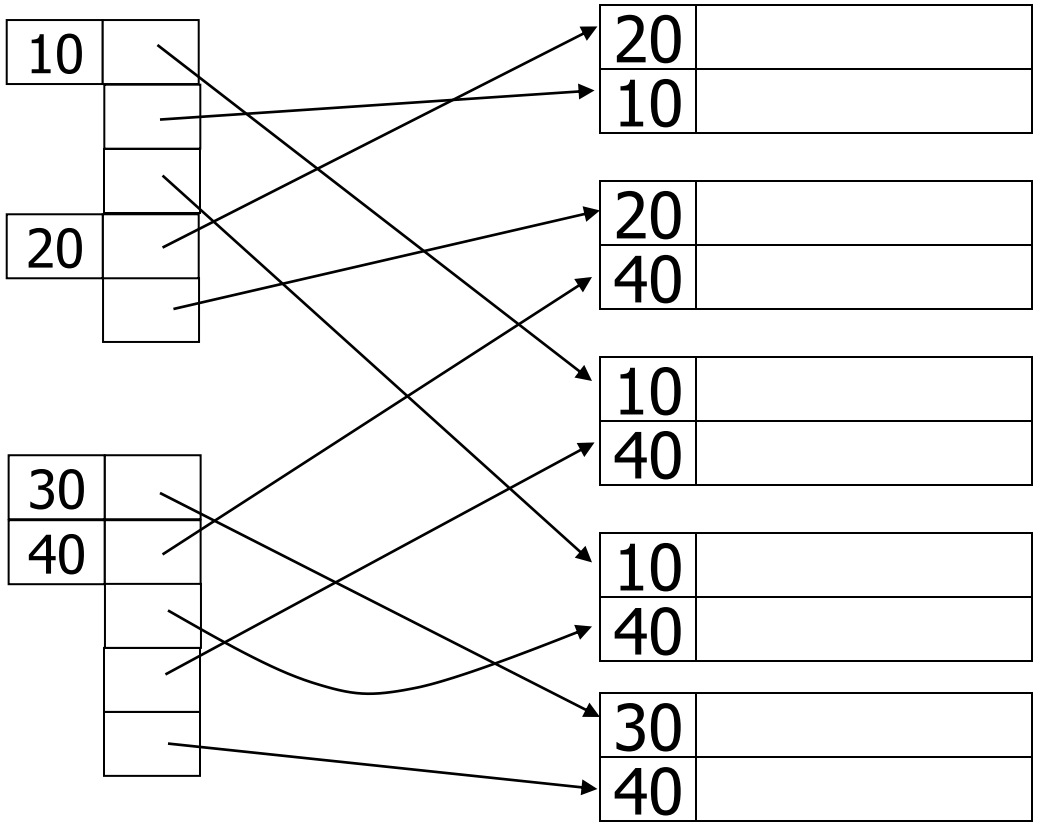
Problem:

excess overhead!

- disk space
- search time

Duplicate values & secondary indexes

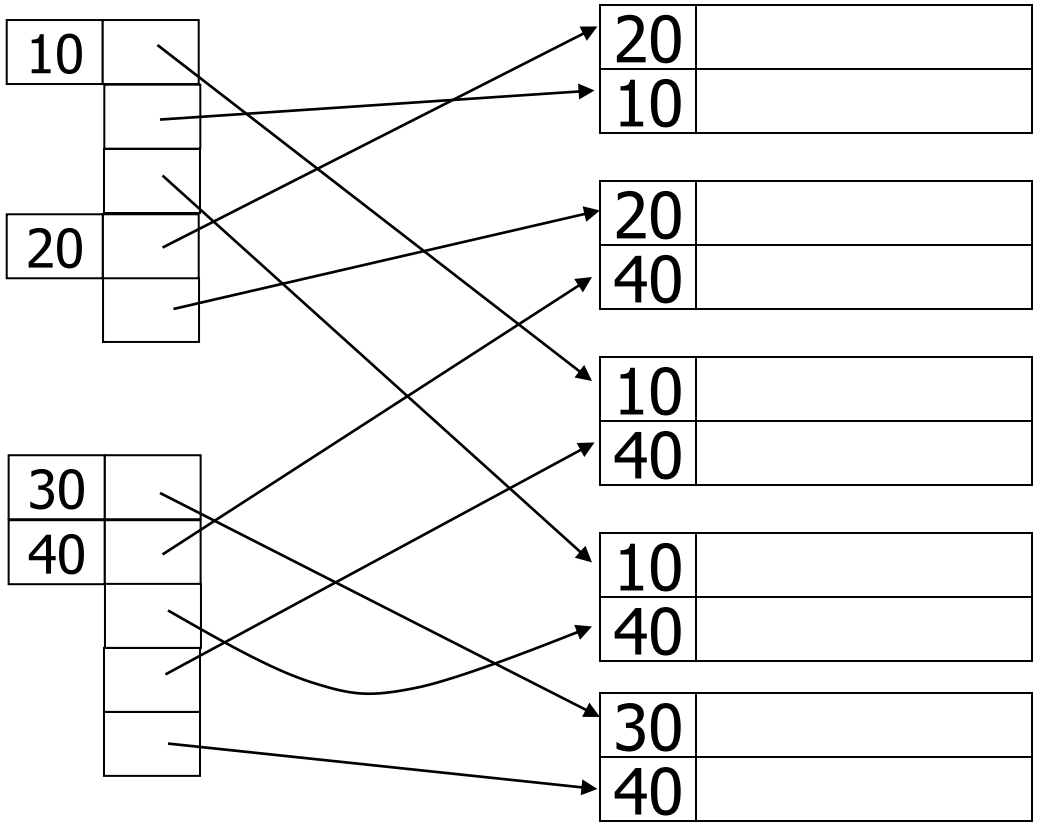
another option...



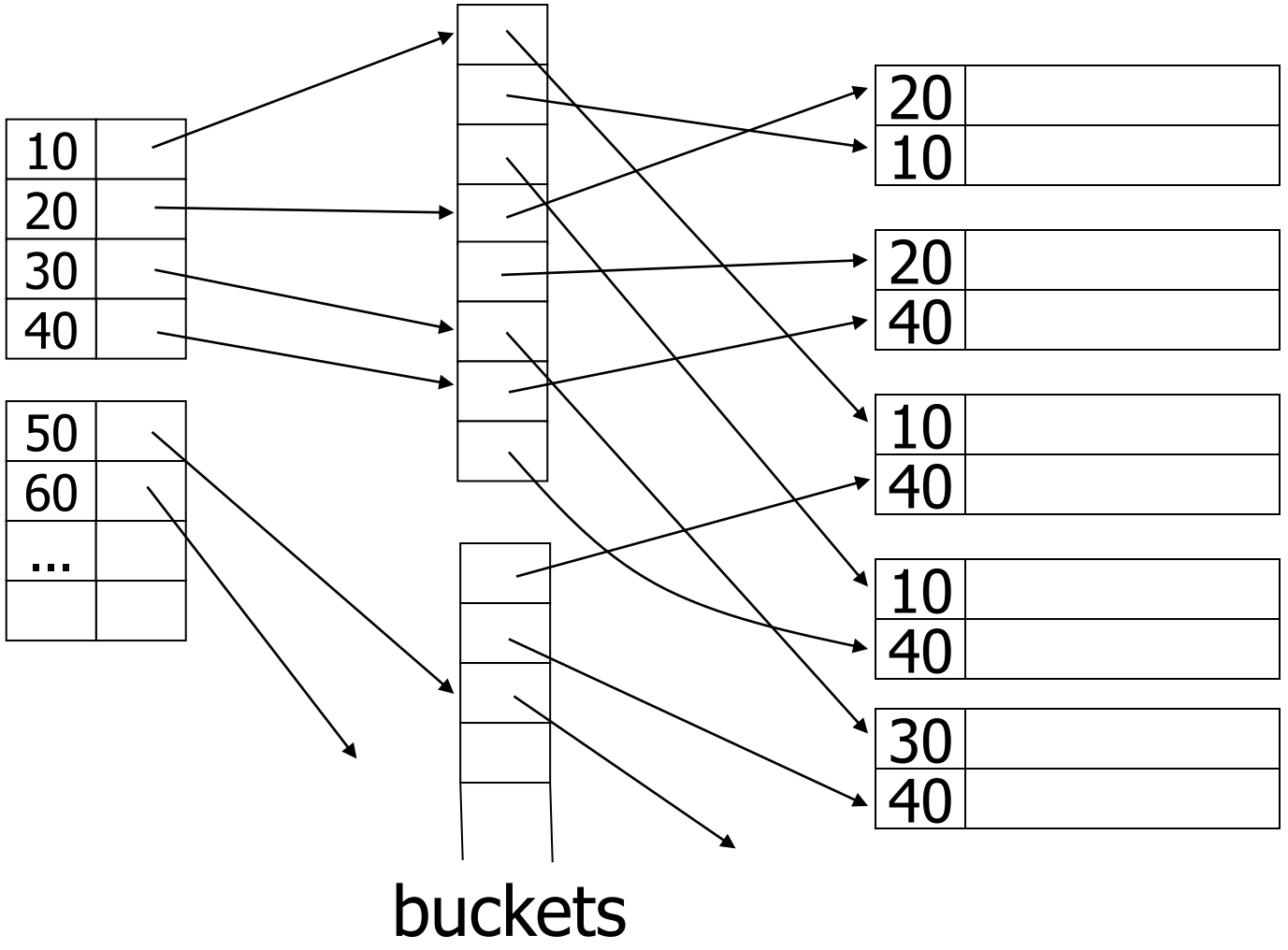
Duplicate values & secondary indexes

another option...

Problem:
variable size
records in
index!



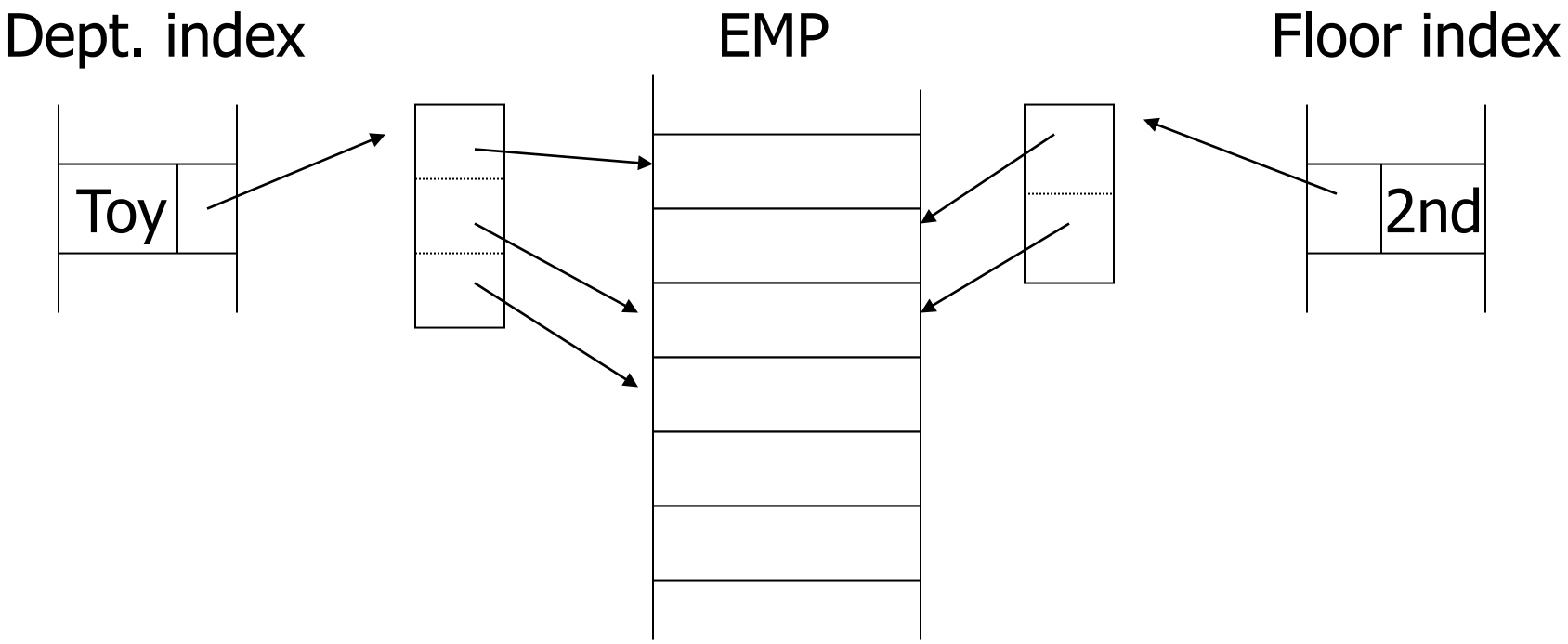
Duplicate values & secondary indexes



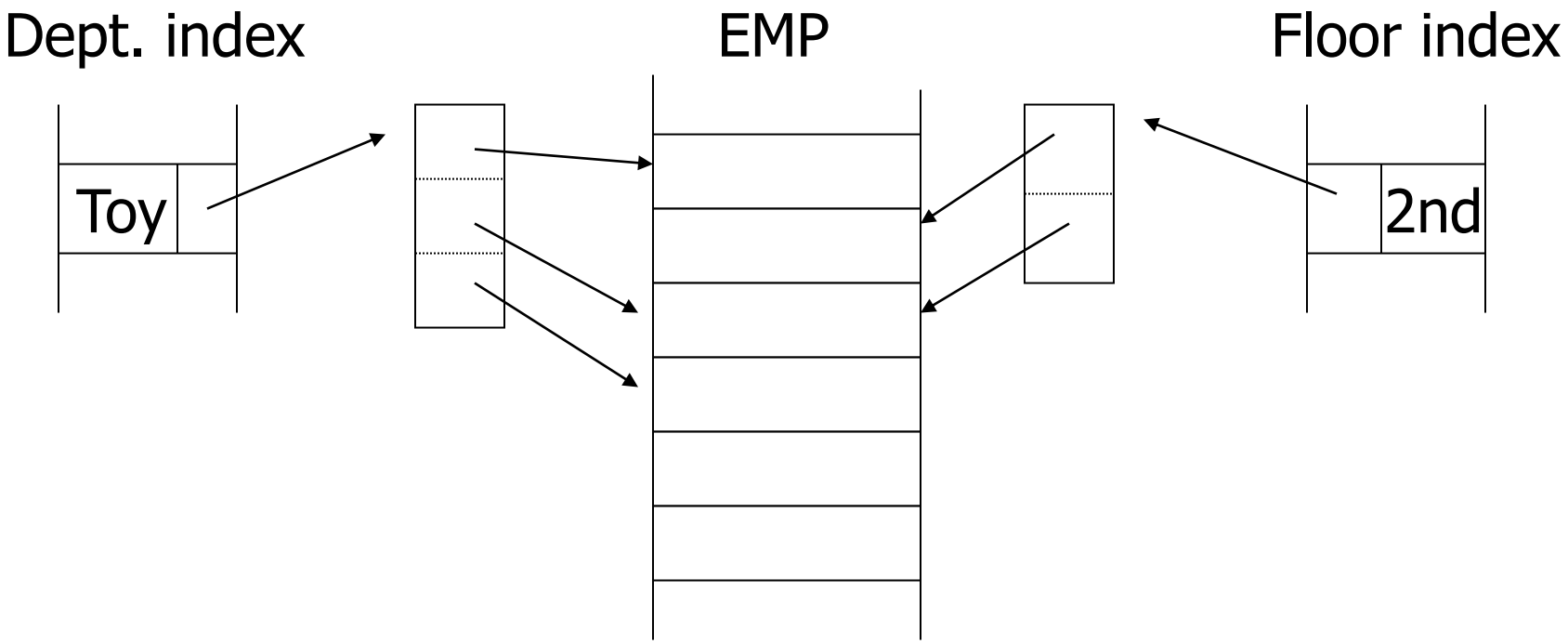
Why "bucket" idea is useful

Indexes	Records
Name: primary	EMP (name,dept,floor,...)
Dept: secondary	
Floor: secondary	

Query: Get employees in (Toy Dept) ∧ (2nd floor)



Query: Get employees in (Toy Dept) $\wedge$ (2nd floor)



$\rightarrow$ Intersect toy bucket and 2nd Floor bucket to get set of matching EMP's

Summary so far

- Conventional index
  - Basic Ideas: sparse, dense, multi-level…
  - Duplicate Keys
  - Deletion/Insertion
  - Secondary indexes

Conventional indexes

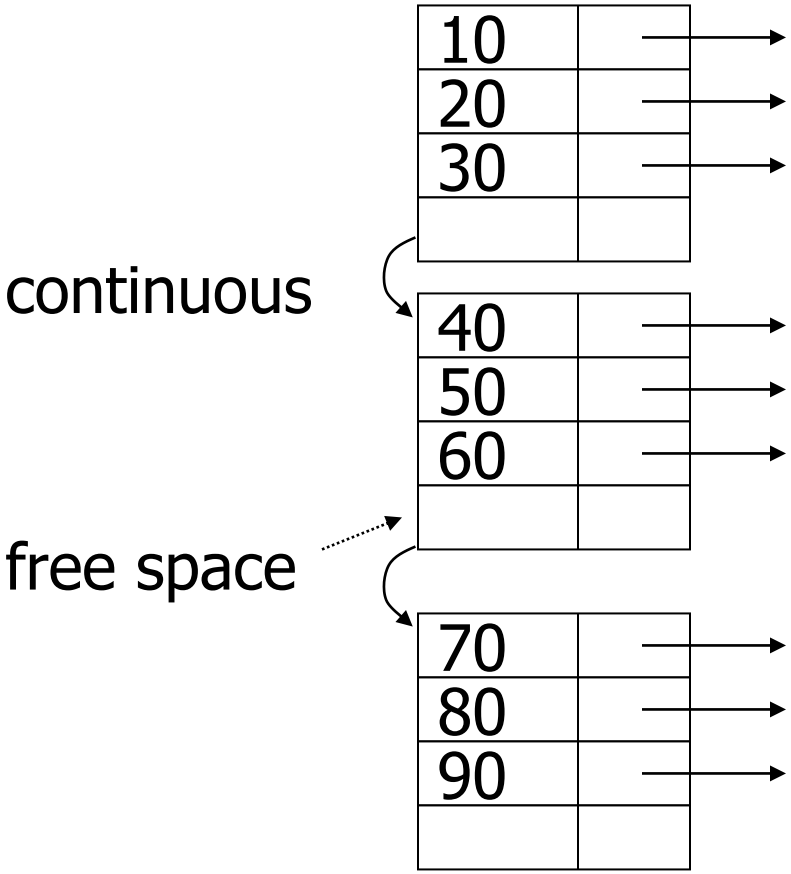
Advantage:

- Simple
- Index is sequential file
  good for scans

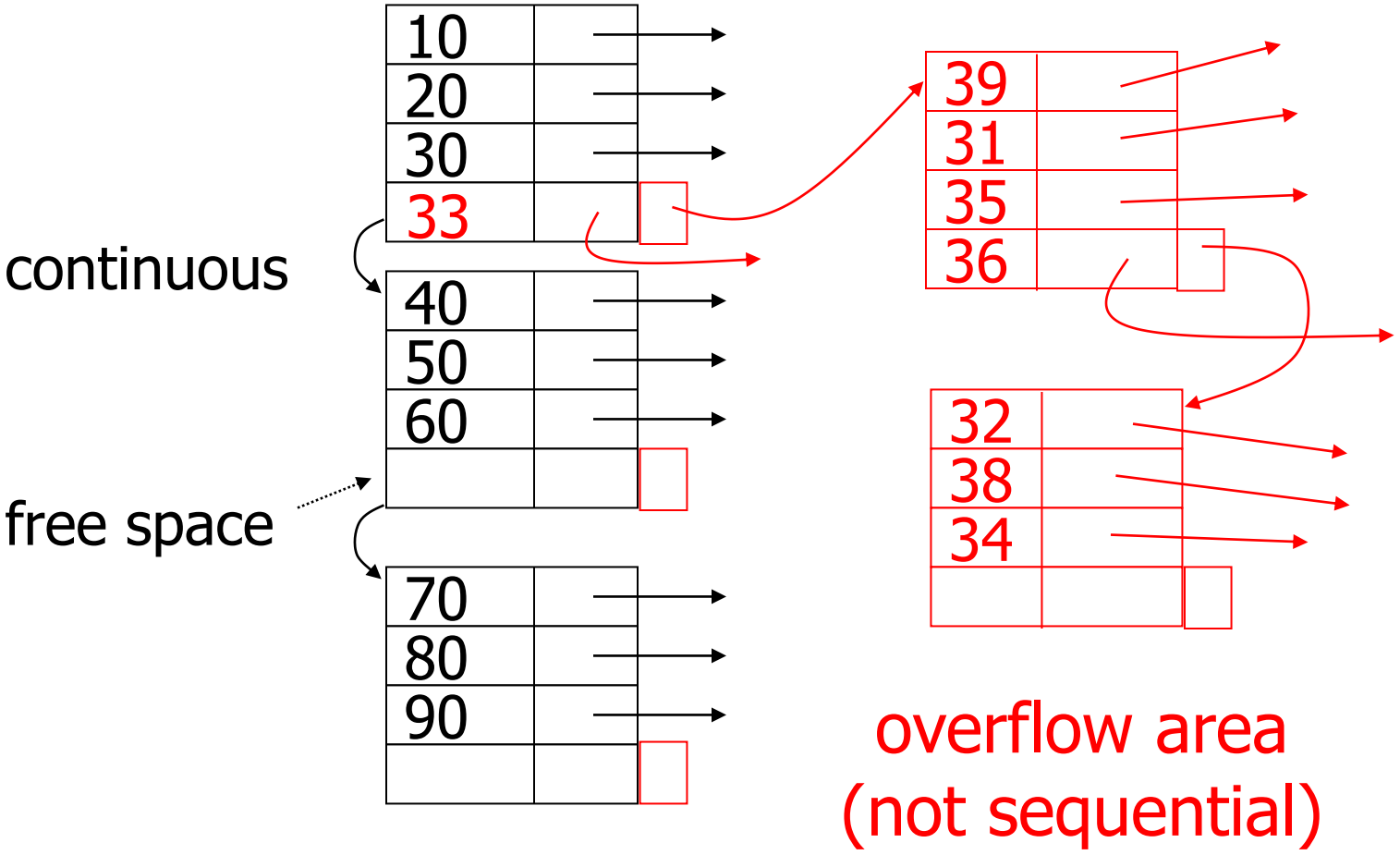
Disadvantage:

- Inserts expensive, or
- Lose sequentiality & balance

Example Index (sequential)



Example Index (sequential)

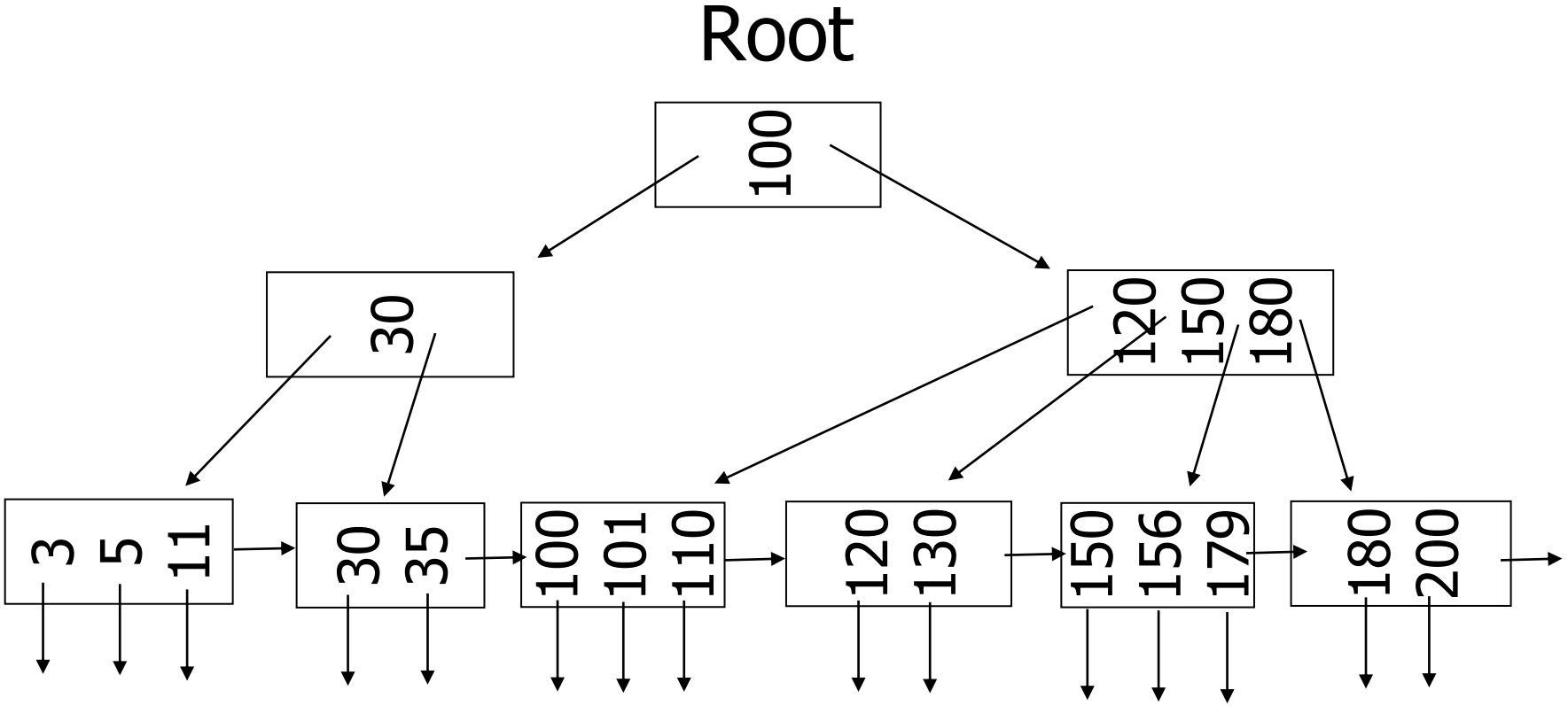


Outline:

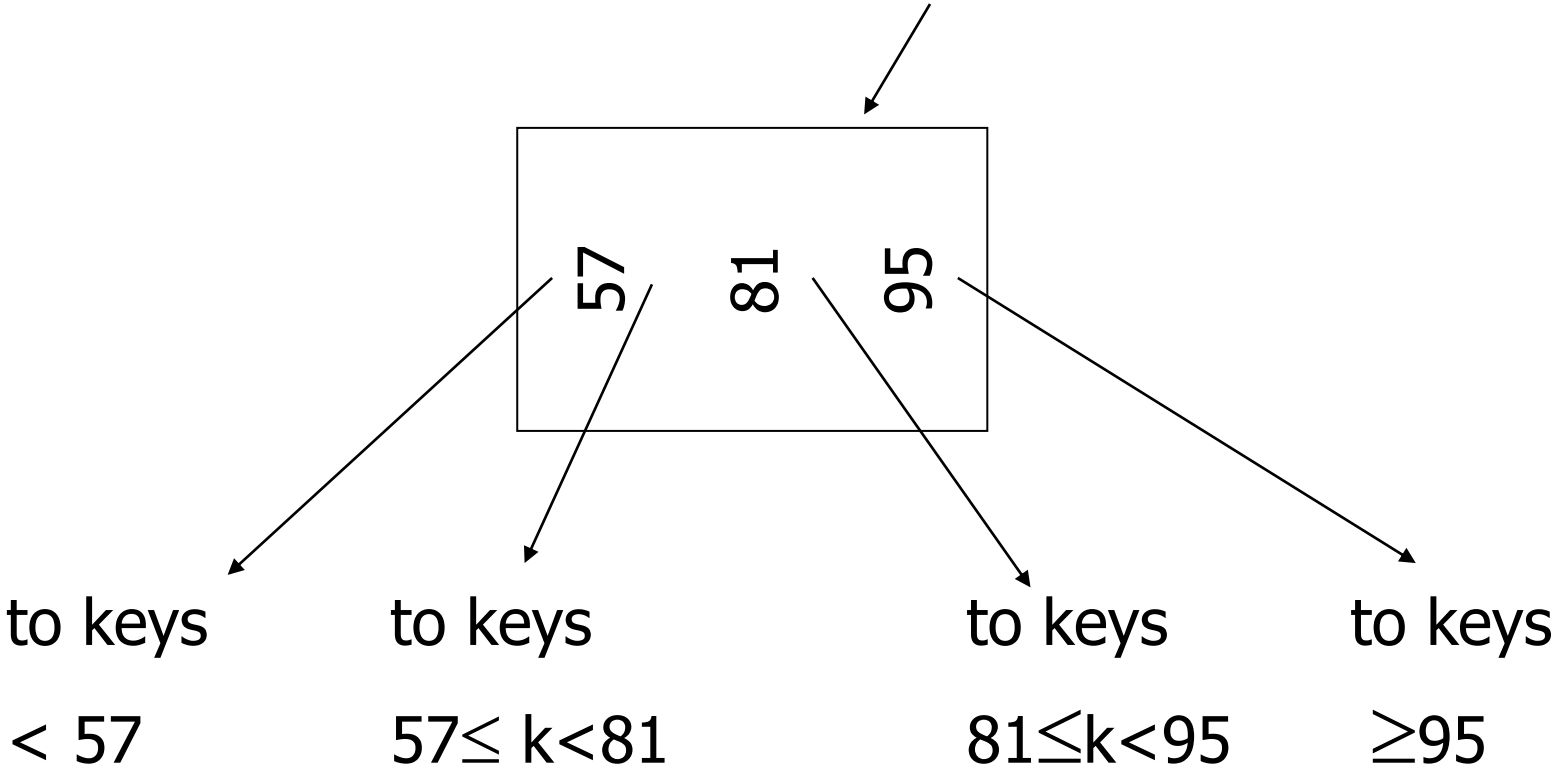
- Conventional indexes
- B-Trees $\Rightarrow$ NEXT
- Hashing schemes

- NEXT: Another type of index
  - Give up on sequentiality of index
  - Try to get “balance”

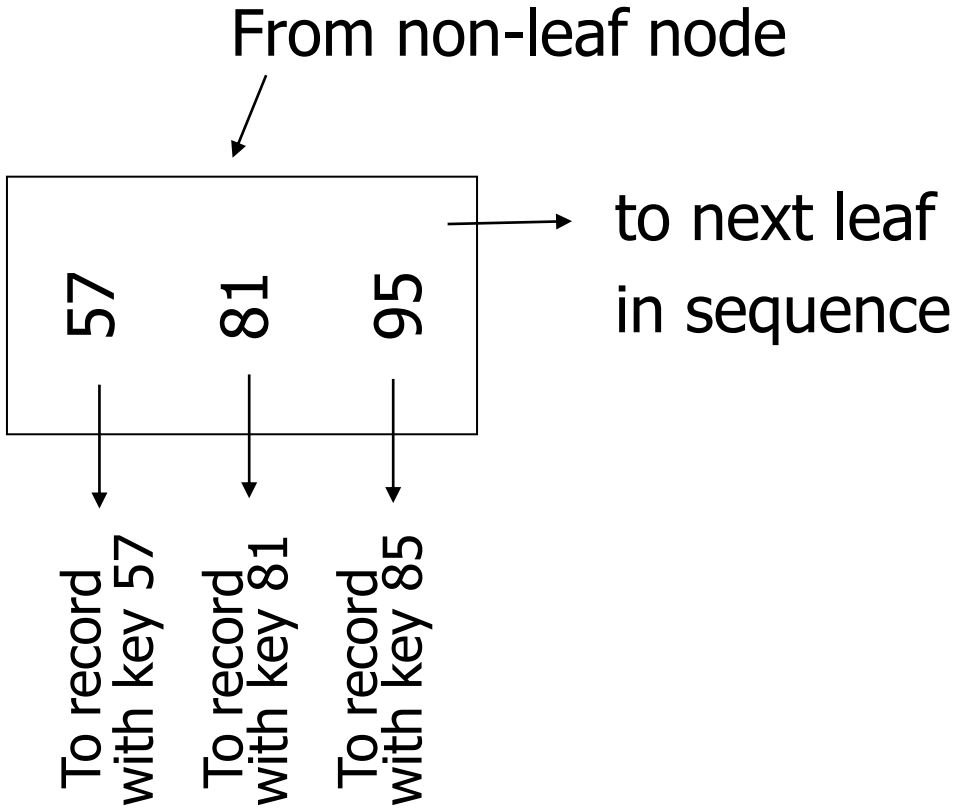
B+Tree Example n=3



Sample non-leaf



Sample leaf node:



Size of nodes: { n+1 pointers, n keys } (fixed)

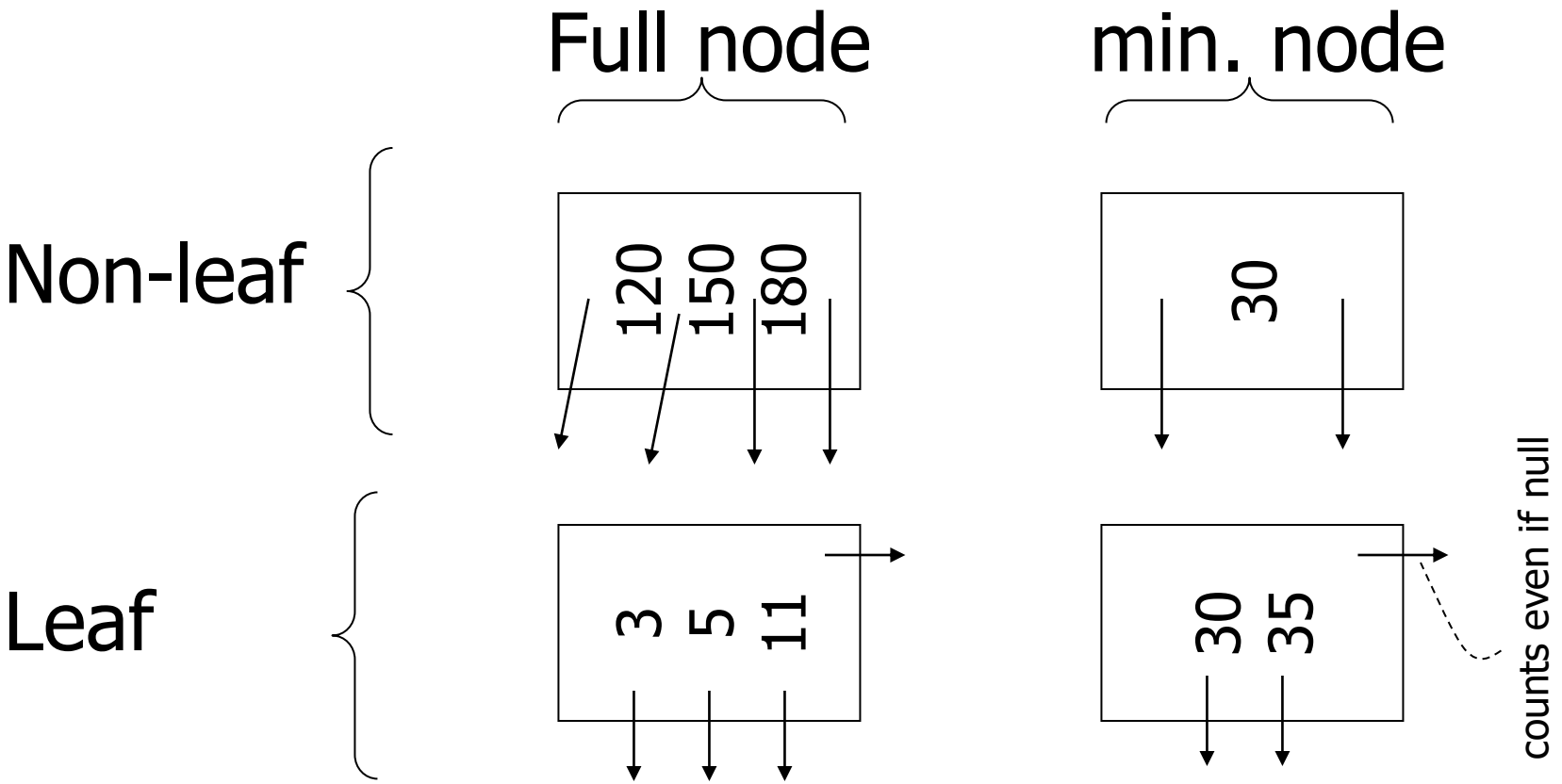
Don't want nodes to be too empty

- Use at least

  Non-leaf: $\lceil (n+1)/2 \rceil$ pointers

  Leaf: $\lfloor (n+1)/2 \rfloor$ pointers to data

n=3


Full node
min. node
Non-leaf
Leaf
120
150
180
30
3
5
11
30
35
counts even if null

B+tree rules — tree of order *n*

(1) All leaves at same lowest level
(balanced tree)

(2) Pointers in leaves point to records
except for "sequence pointer"

(3) Number of pointers/keys for B+tree

	Max ptrs	Max keys	Min ptrs→data	Min keys
Non-leaf (non-root)	n+1	n	$\lceil (n+1)/2 \rceil$	$\lceil (n+1)/2 \rceil - 1$
Leaf (non-root)	n+1	n	$\lfloor (n+1)/2 \rfloor$	$\lfloor (n+1)/2 \rfloor$
Root	n+1	n	1	1

Insert into B+tree

(a) simple case
  - space available in leaf

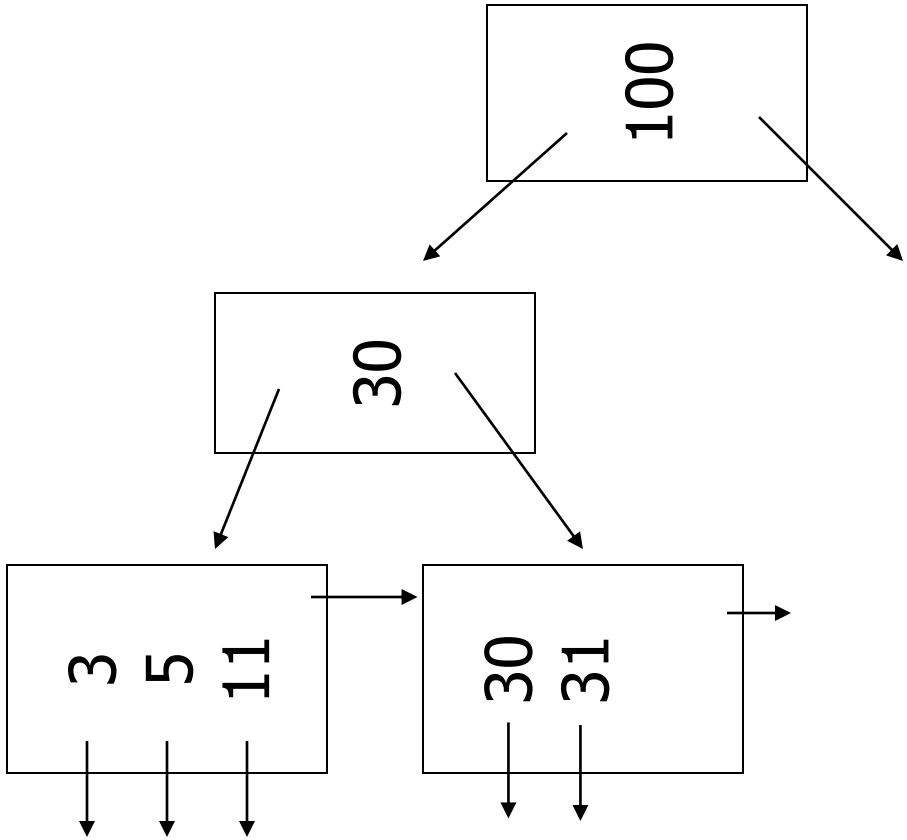
(b) leaf overflow

(c) non-leaf overflow

(d) new root

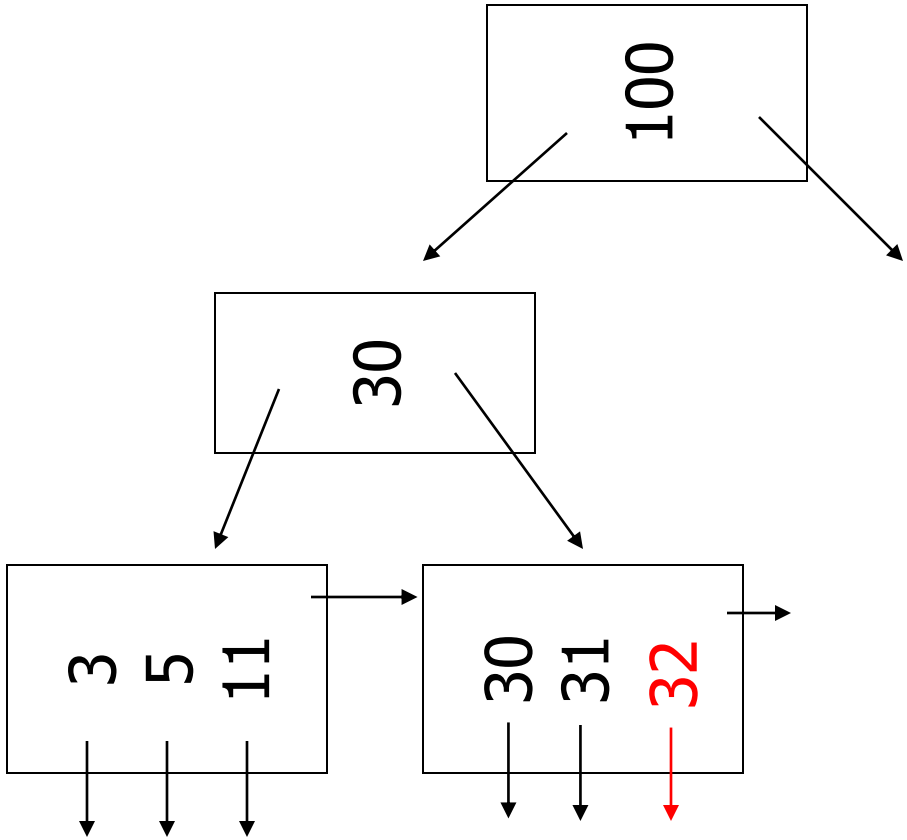
(a) Insert key = 32

n=3



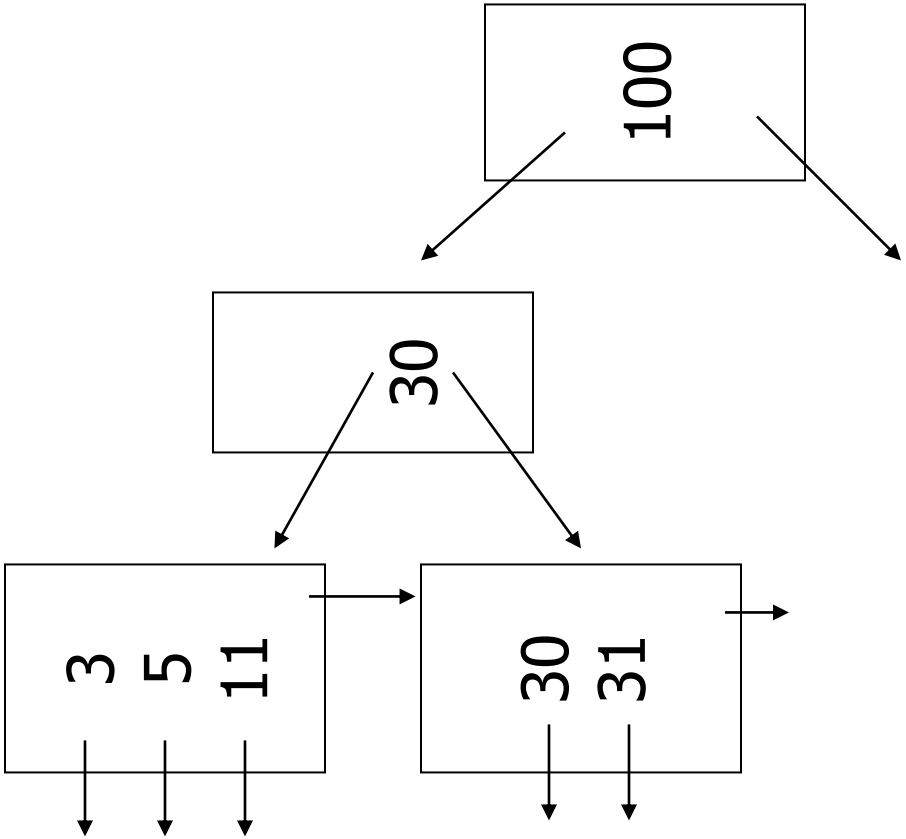
(a) Insert key = 32

n=3



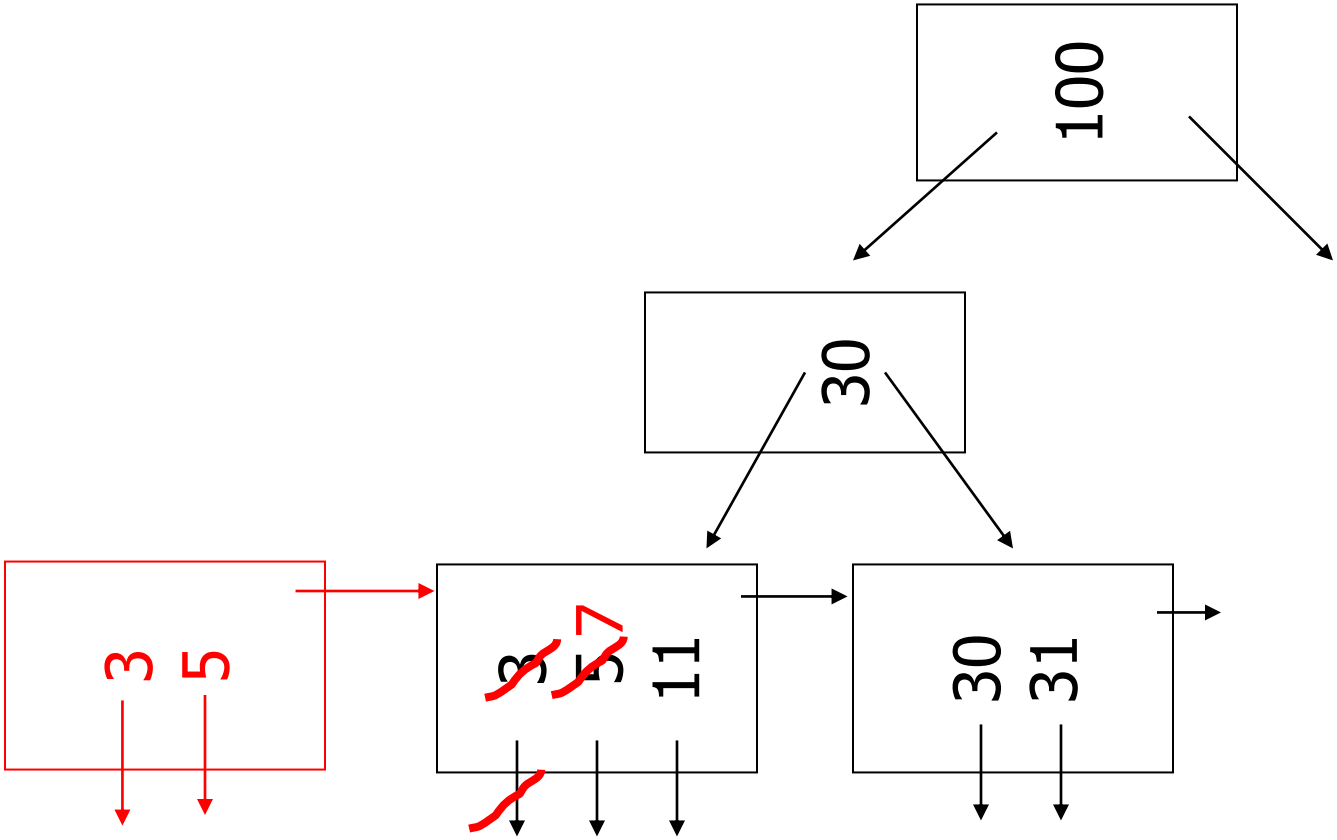
(a) Insert key = 7

n=3



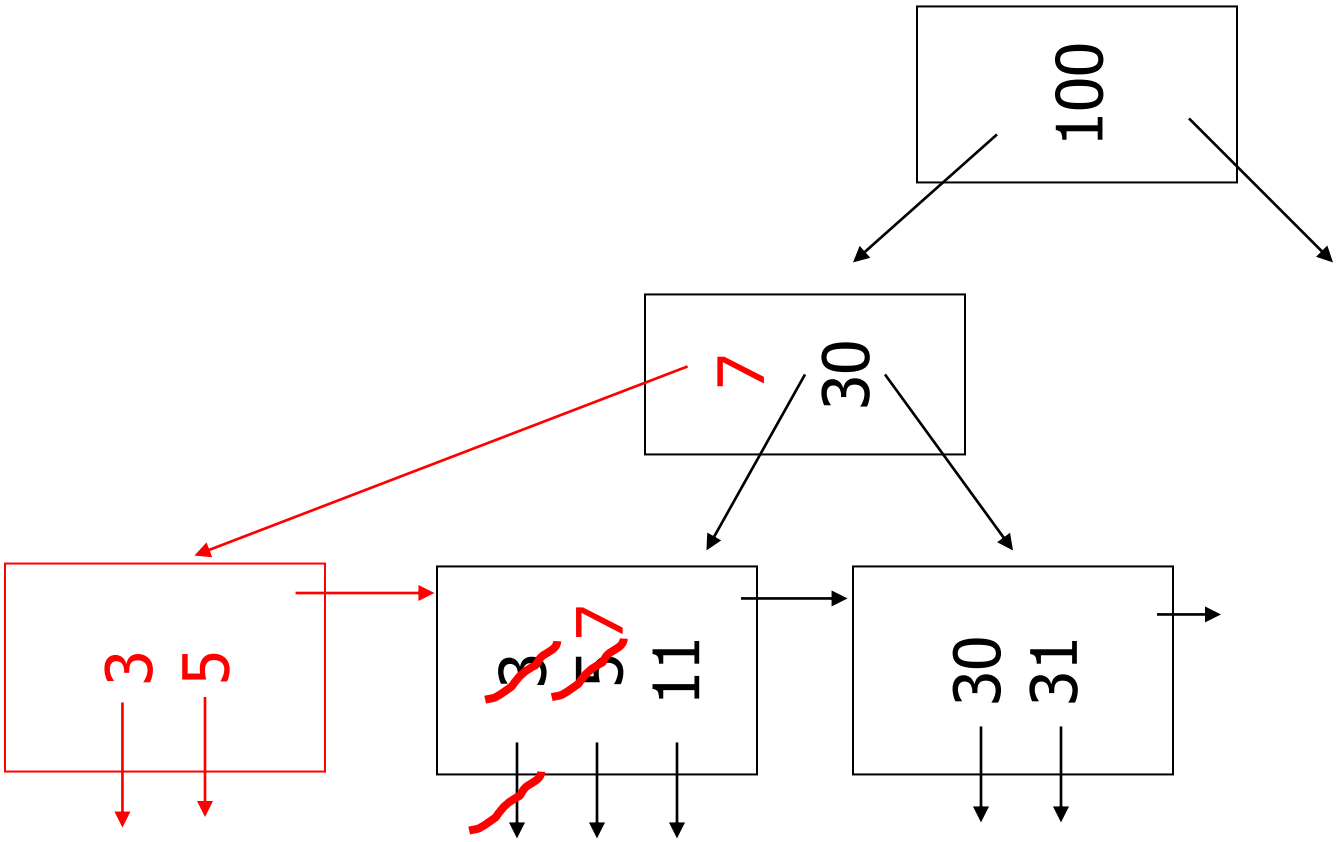
(a) Insert key = 7

n=3



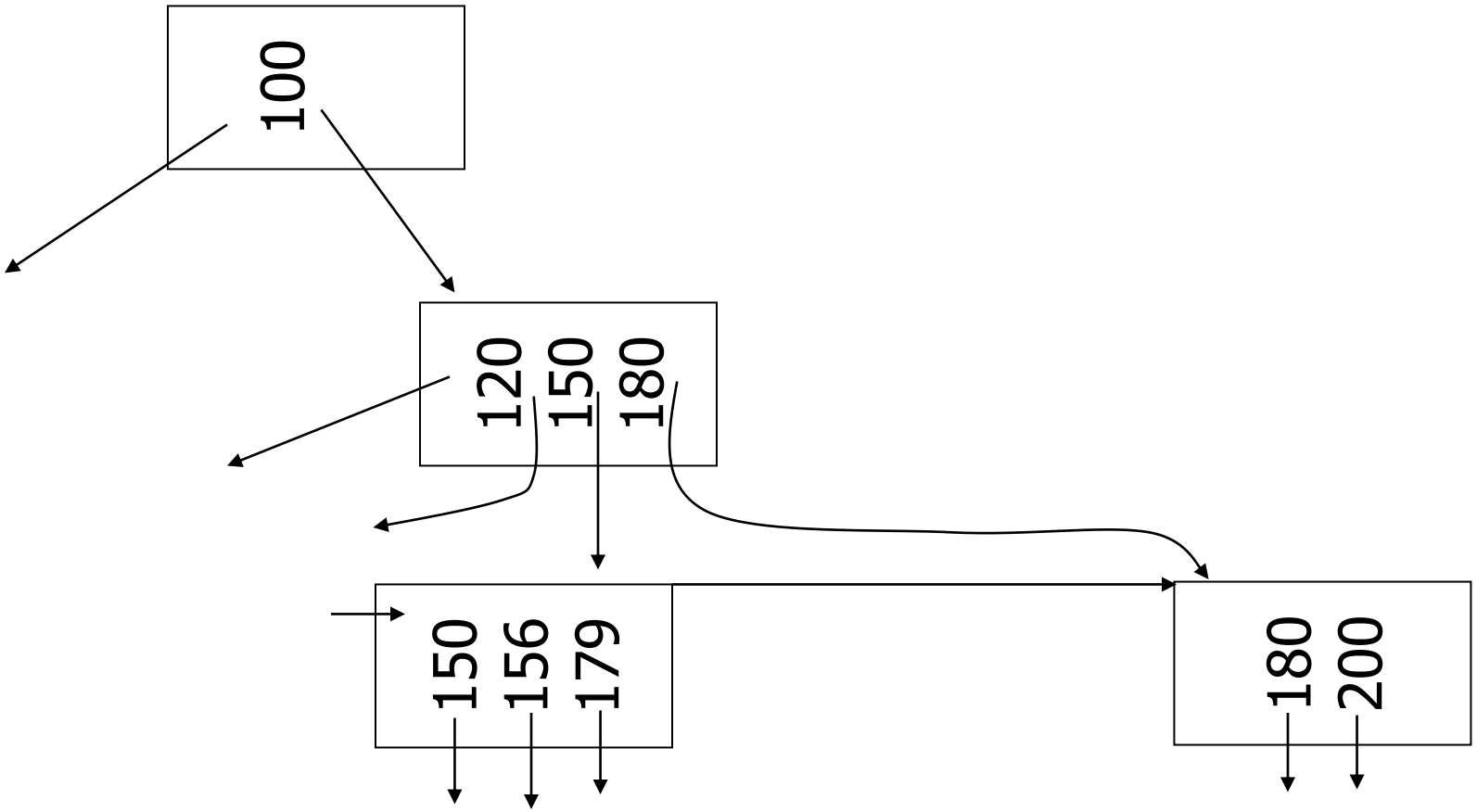
(a) Insert key = 7

n=3



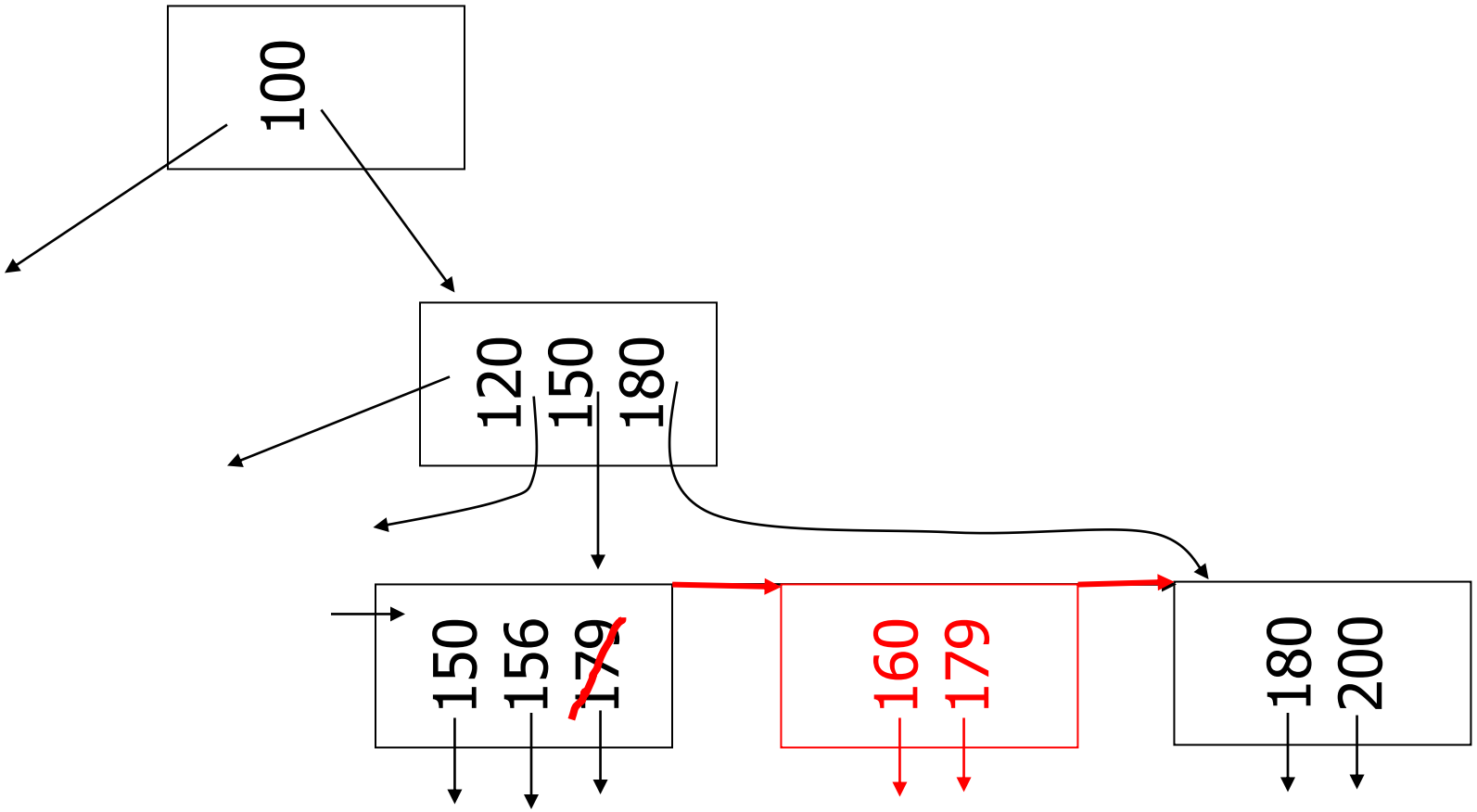
(c) Insert key = 160

n=3



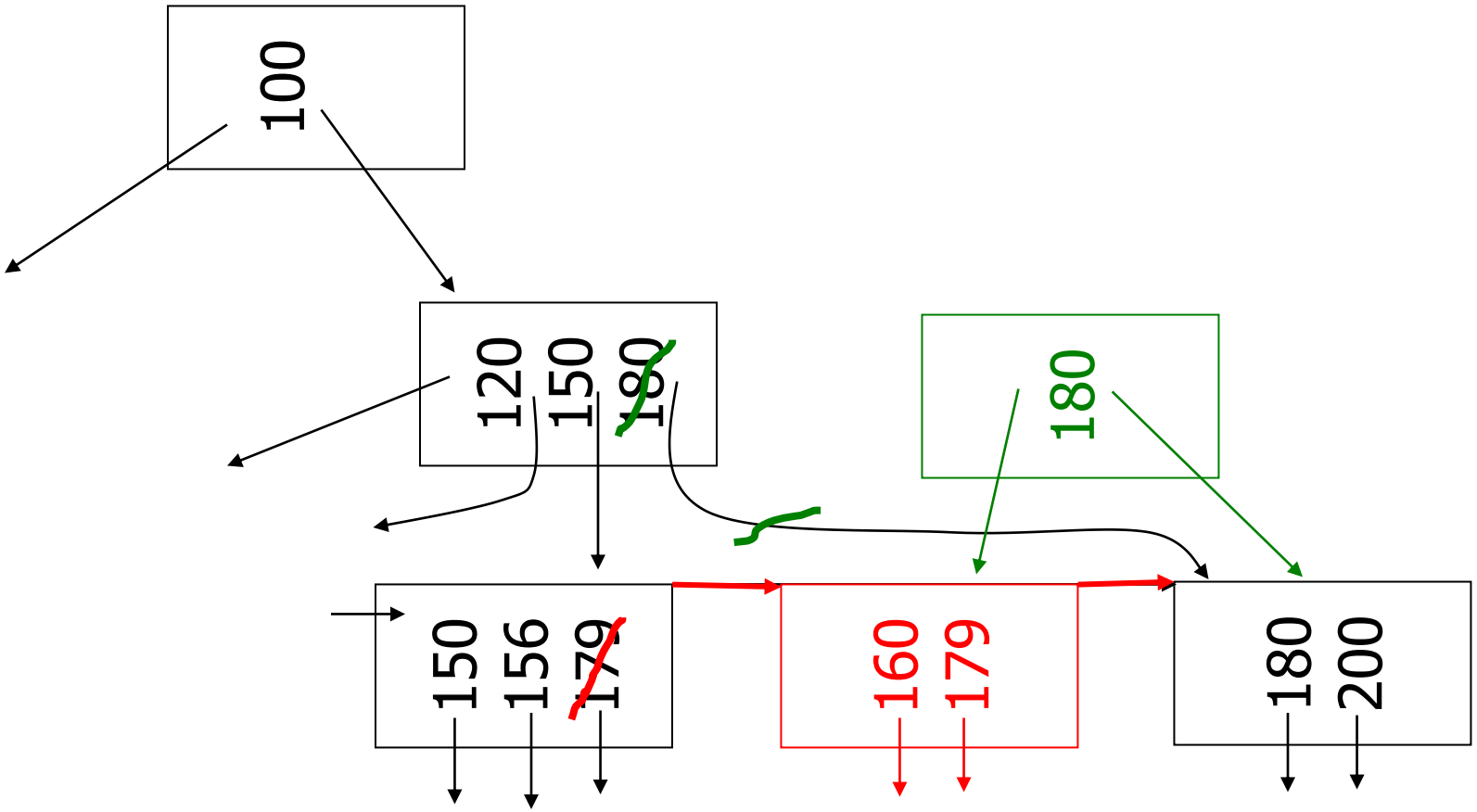
(c) Insert key = 160

n=3



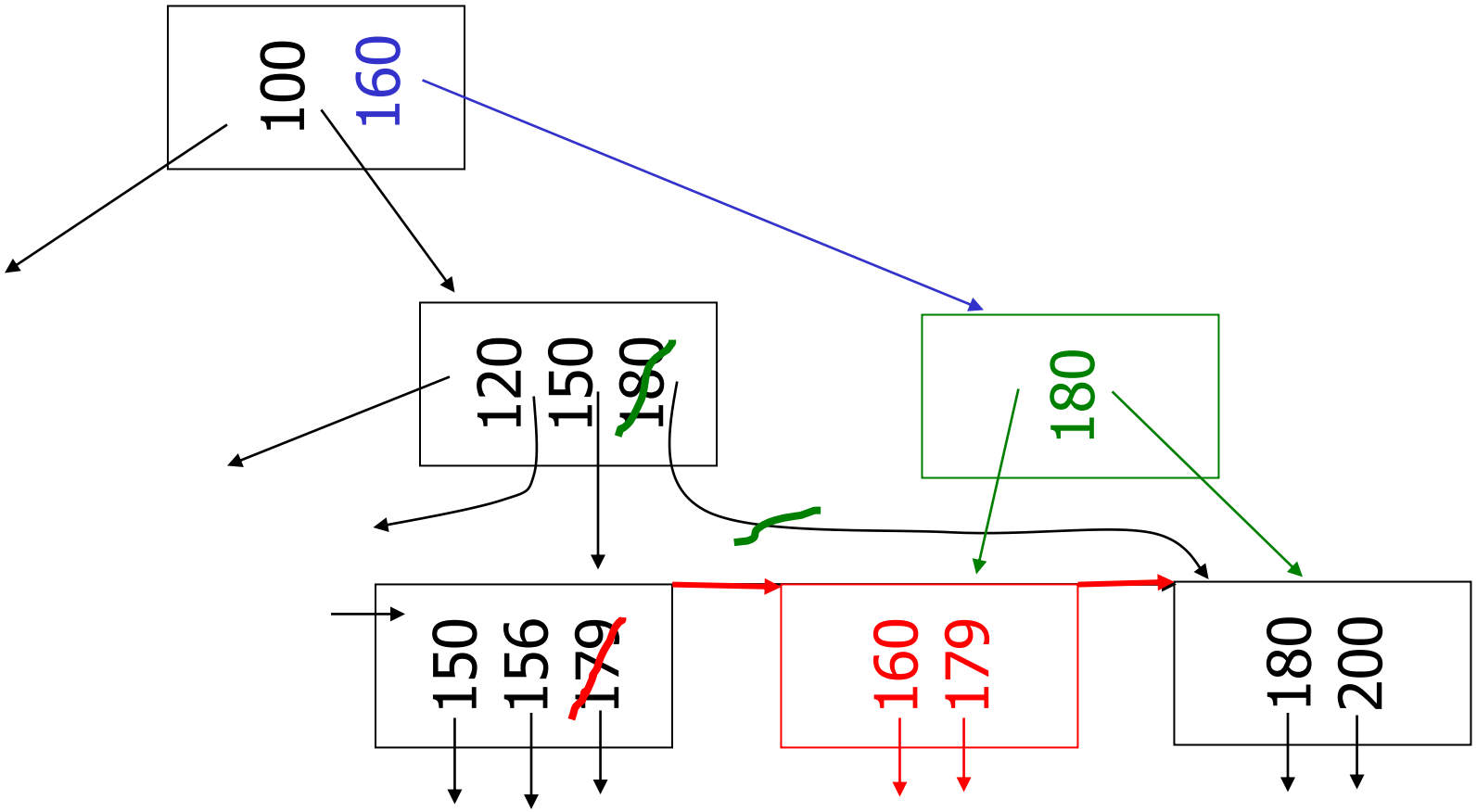
(c) Insert key = 160

n=3



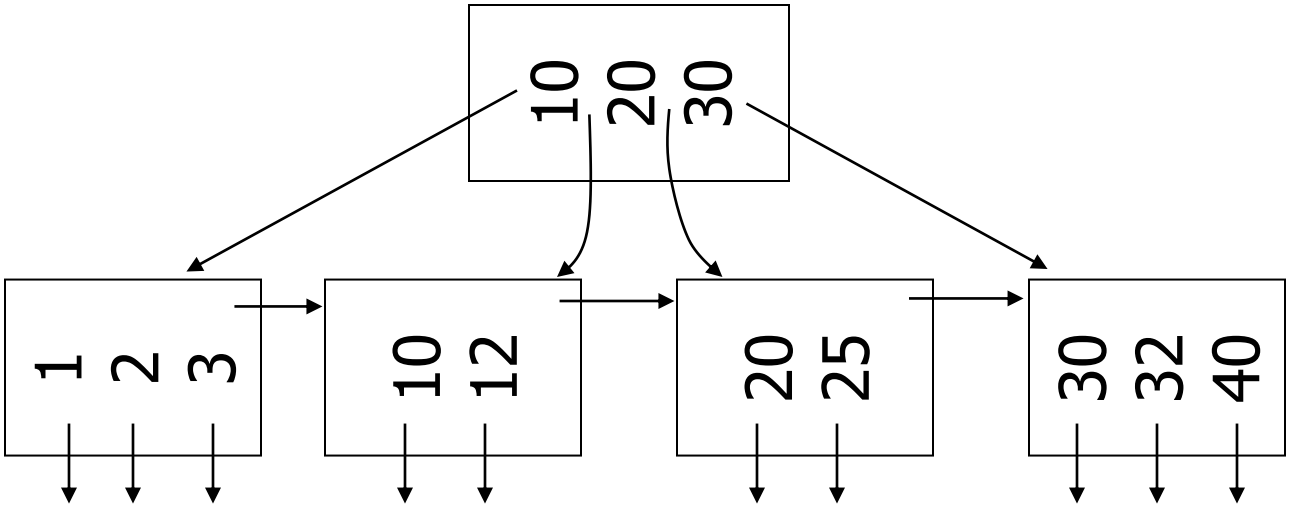
(c) Insert key = 160

n=3



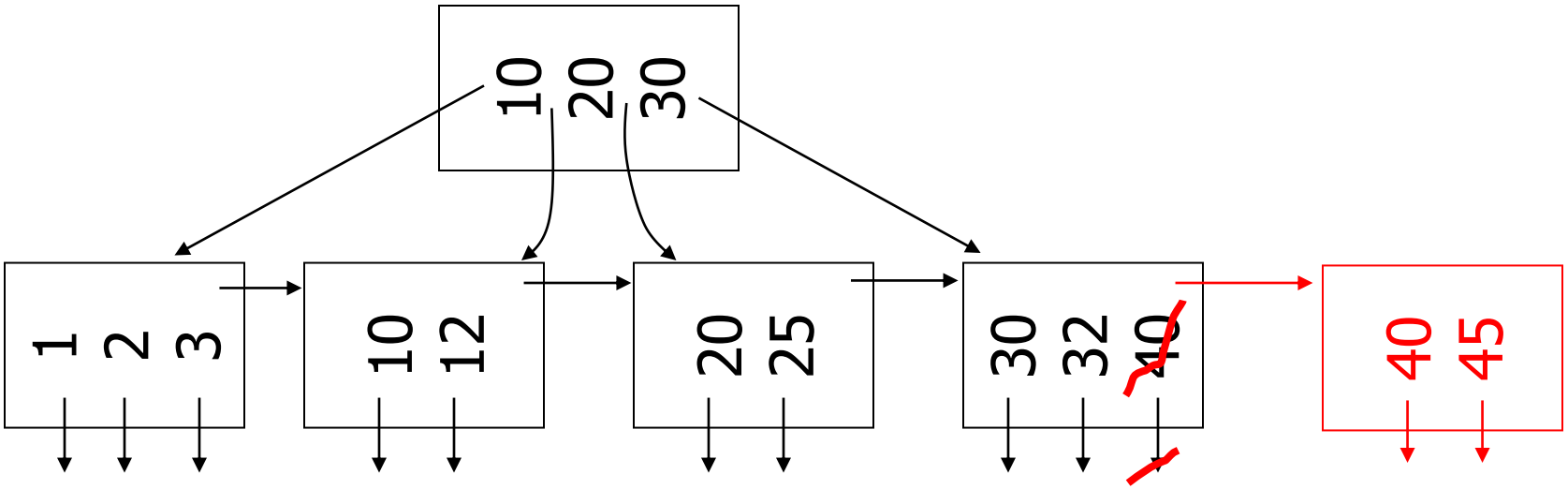
(d) New root, insert 45

n=3



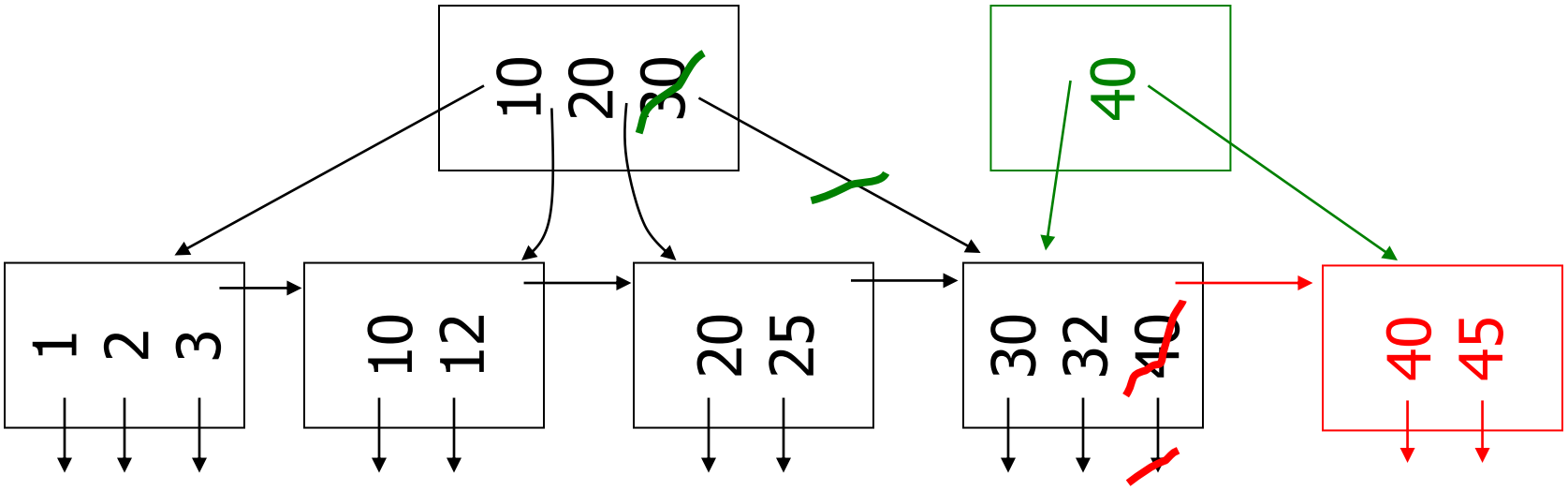
(d) New root, insert 45

n=3



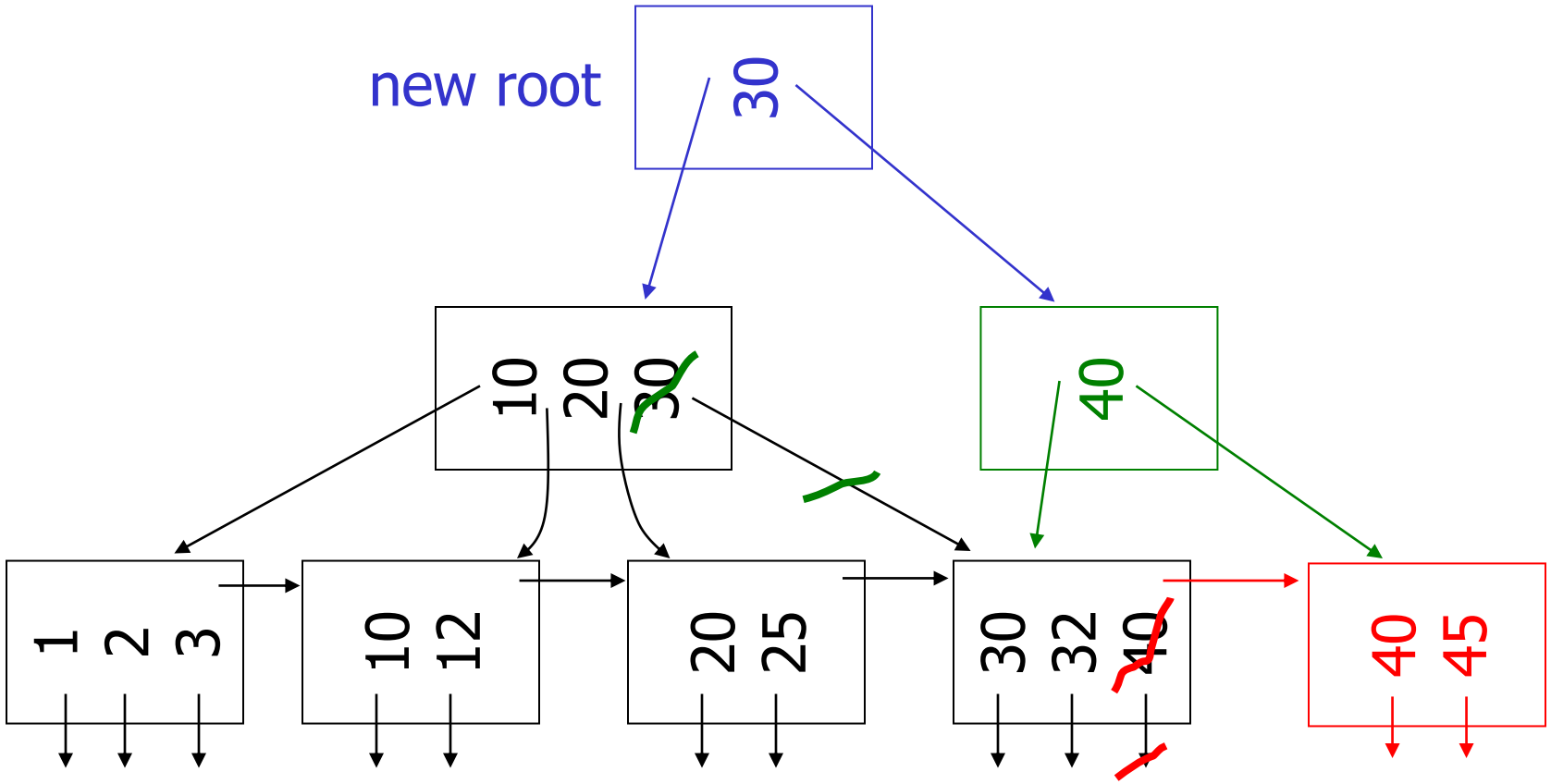
(d) New root, insert 45

n=3



(d) New root, insert 45

n=3



Deletion from B+tree

(a) Simple case - no example

(b) Coalesce with neighbor (sibling)

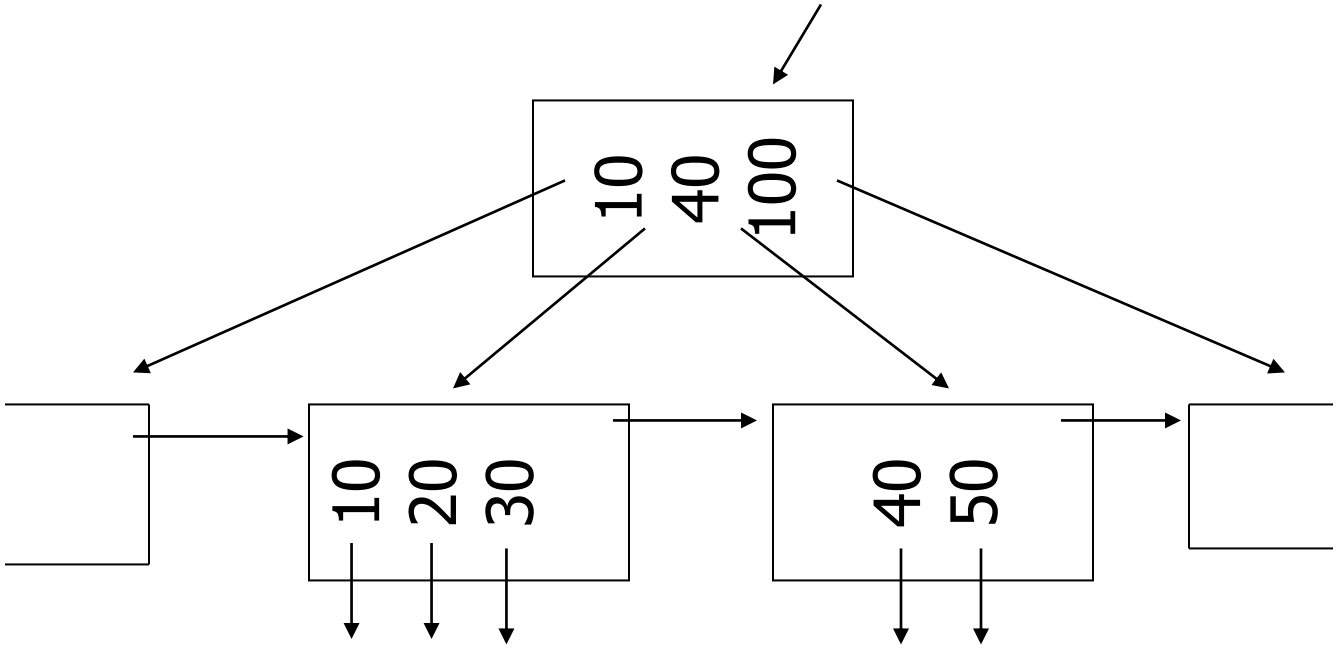
(c) Re-distribute keys

(d) Cases (b) or (c) at non-leaf

(b) Coalesce with sibling

– Delete 50

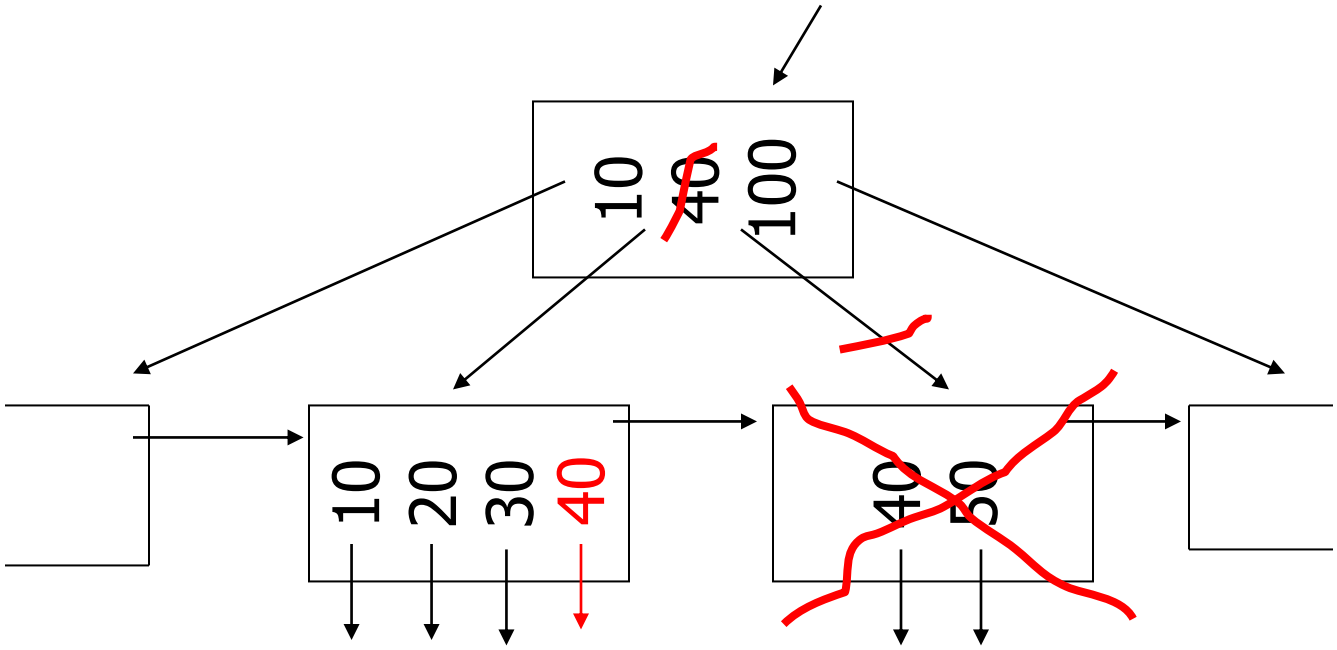
n=4



(b) Coalesce with sibling

– Delete 50

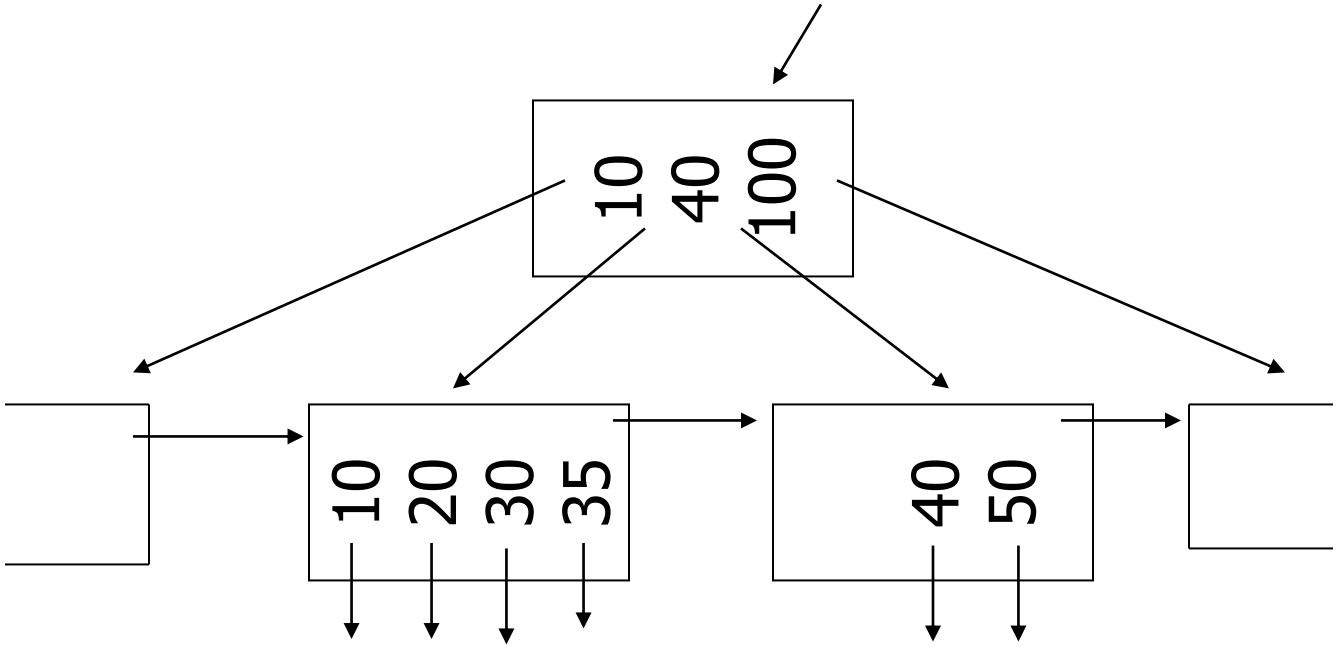
n=4



(c) Redistribute keys

– Delete 50

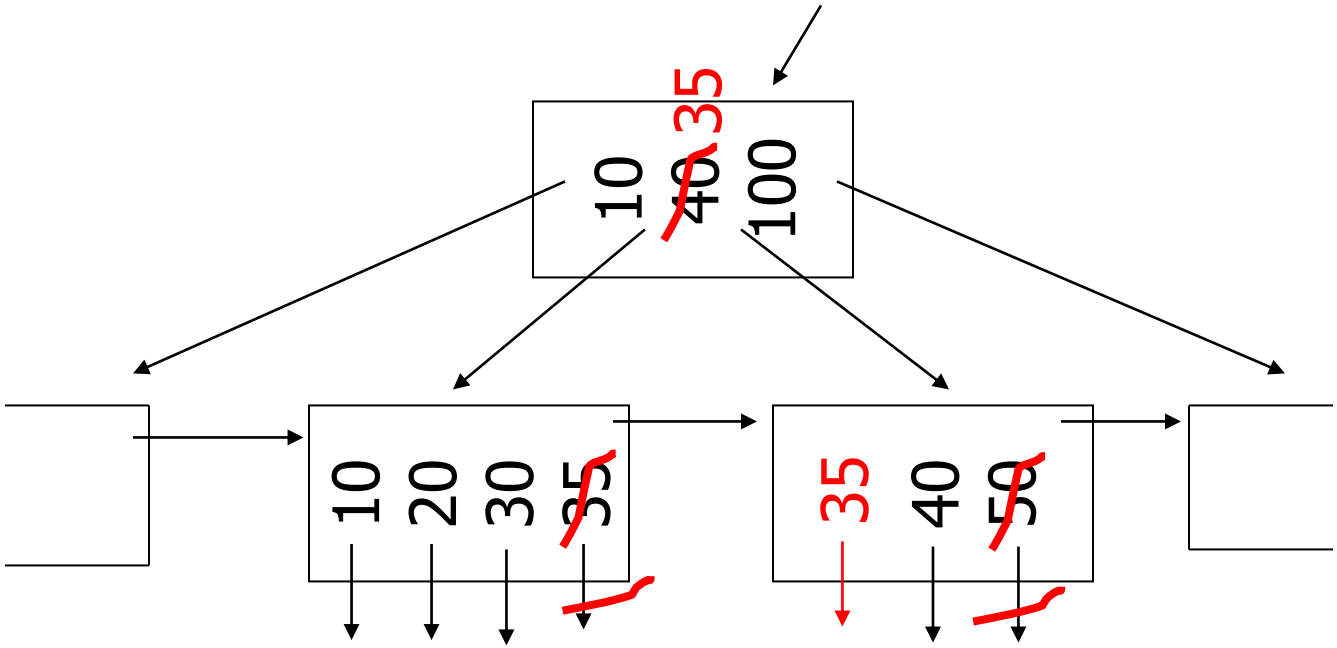
n=4



(c) Redistribute keys

– Delete 50

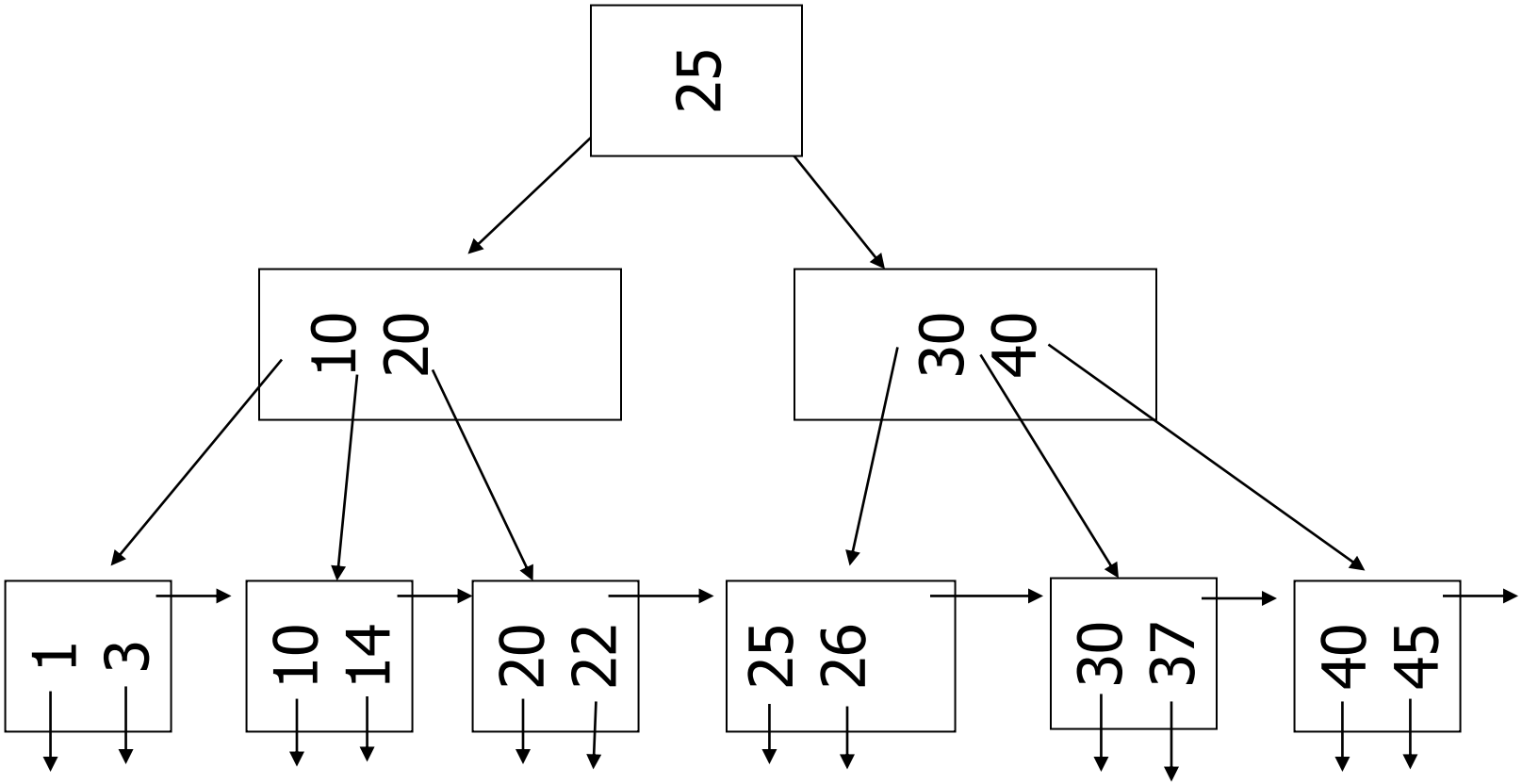
n=4



(d) Non-leaf coalesce

– Delete 37

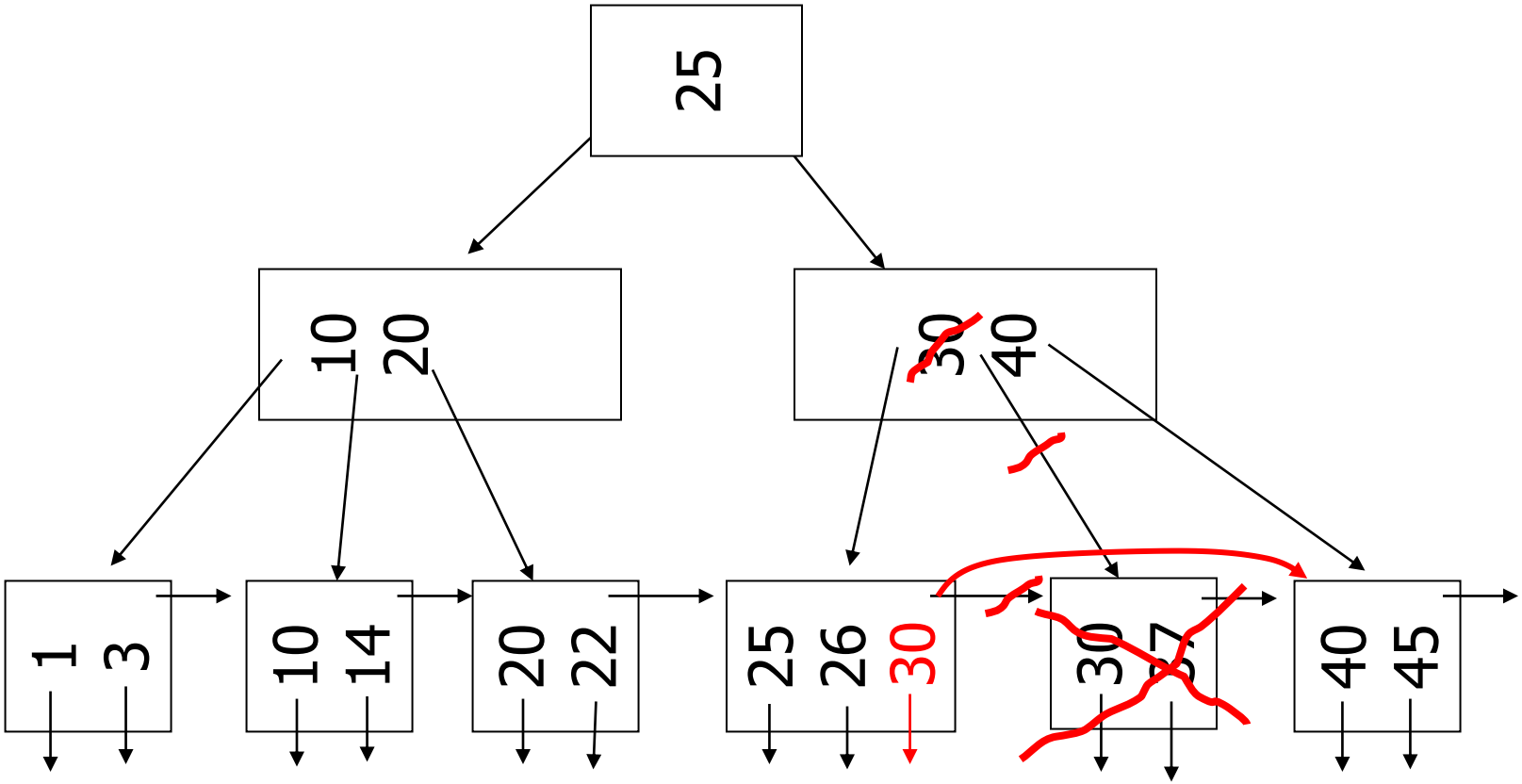
n=4



(d) Non-leaf coalesce

– Delete 37

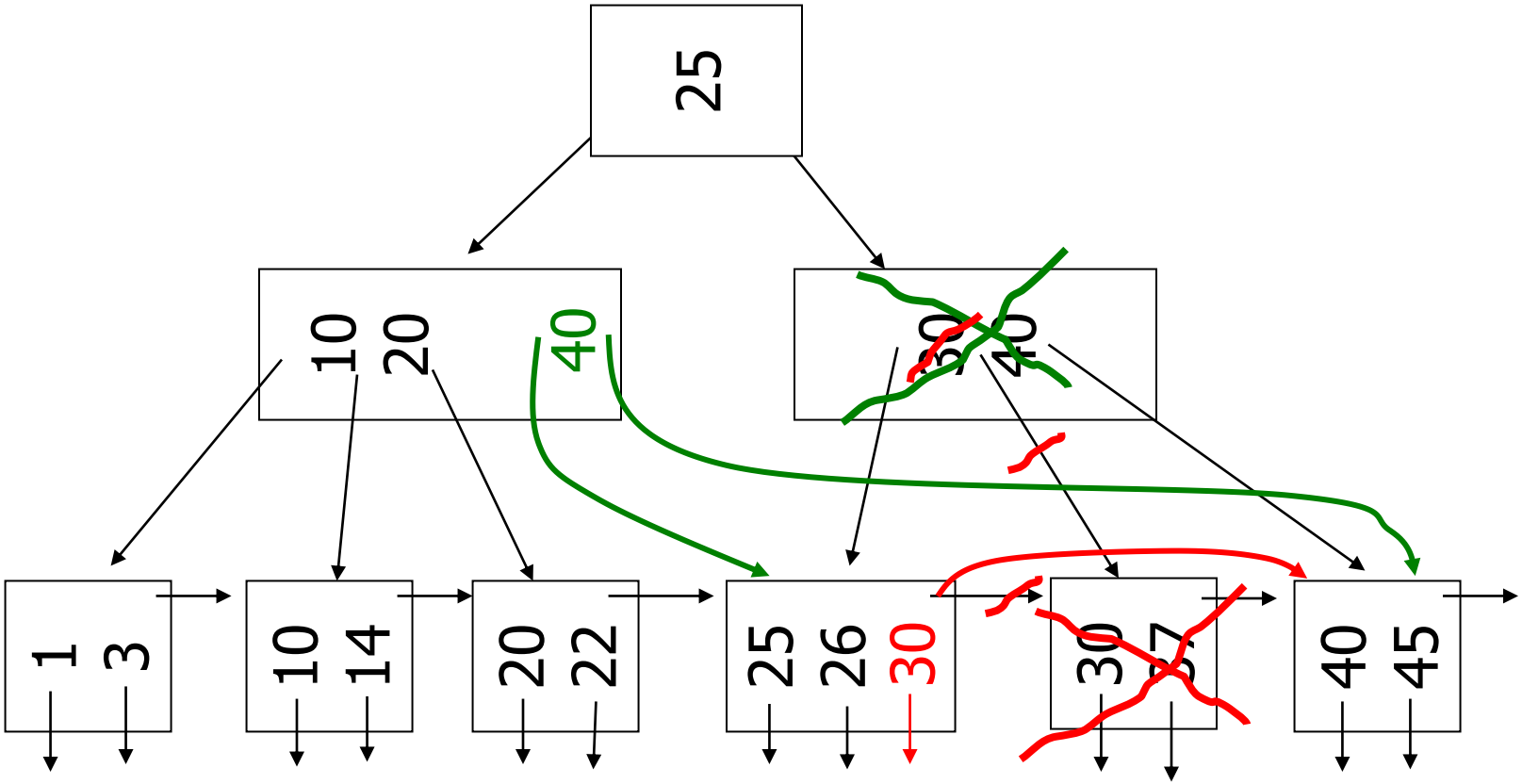
n=4



(d) Non-leaf coalesce

– Delete 37

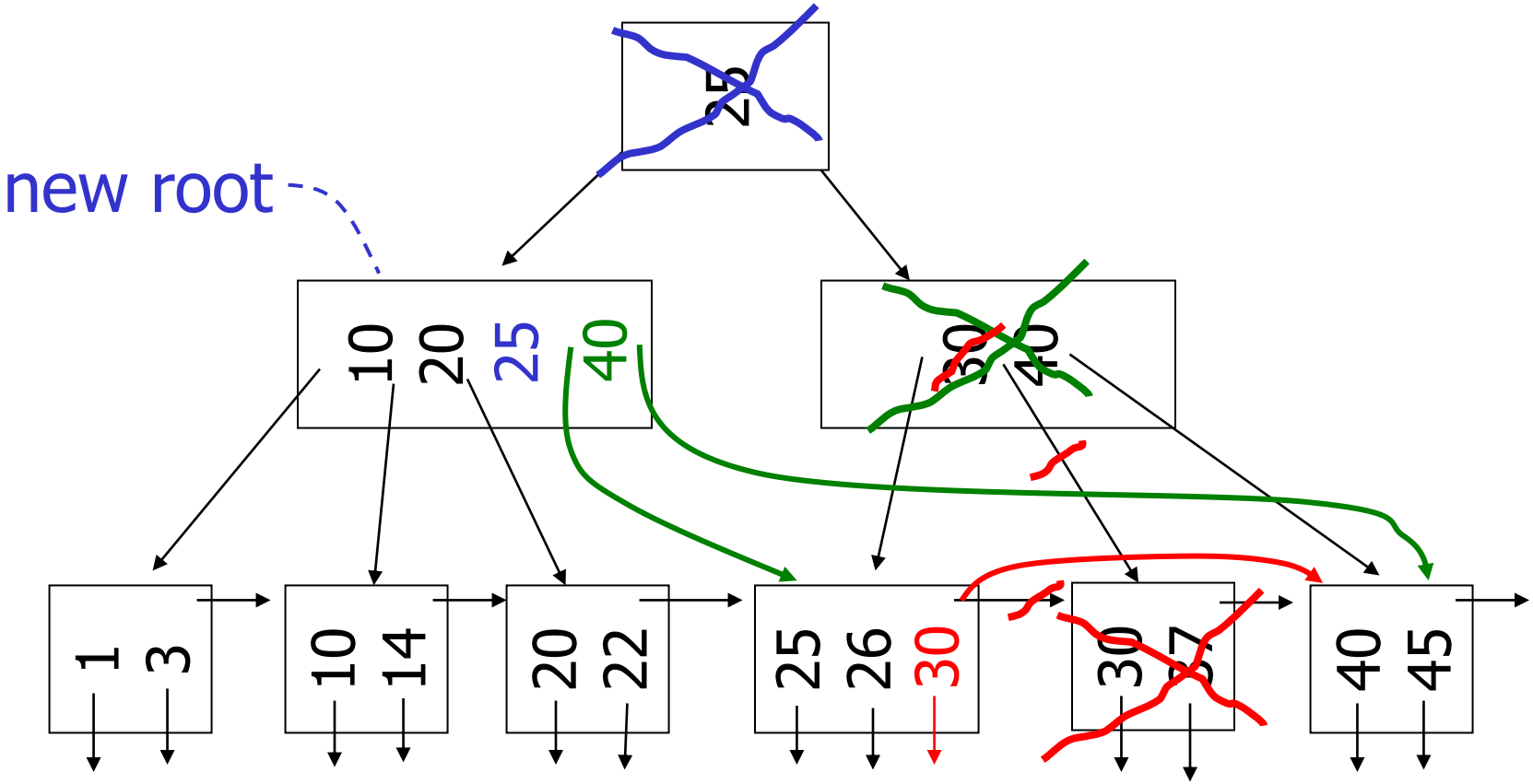
n=4



(d) Non-leaf coalesce

– Delete 37

n=4



B+tree deletions in practice

- Often, coalescing is not implemented
  - Too hard and not worth it!

Outline/summary

- Conventional Indexes
  - Sparse vs. dense
  - Primary vs. secondary
- B trees
- Hashing schemes (recommended reading, not mandatory)

The slides in this lecture are taken from:

- Hector Garcia-Molina, CS 245: Database System Principles, Notes 4: Indexing.

Reading

- Héctor García-Molina, Jeffrey Ullman, and Jennifer Widom. Database Systems: The Complete Book