Database Administration

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Motivation

- Problem:
  - select x from Y
    where z = 'k';

- Plan:

 select z = 'k'

  ↑

  scan Y

- Cost?

z	x
d	2
c	6
g	2
k	**2**
h	3
a	1
b	1
f	3
d	2
k	**1**
j	2
l	1
...	...

Index

- Makes it easy to find pages containing interesting data

- Smaller that data
  - Fits in memory?

- Efficient look-up:
  - Identity (=)
  - Ranges
  - LIKE
  - ...

z	x
d	2
c	6
g	2
k	**2**
h	3
a	1
b	1
f	3
d	2
k	**1**
j	2
l	1
...	...

B-Tree

a
b
c
d
e
f
next

a
g
l
...
next   X

g
h
i
j
k
k
next

z	x
d	2
c	6
g	2
k	**2**
h	3
a	1
b	1
f	3
d	2
k	**1**
j	2
l	1
...	...
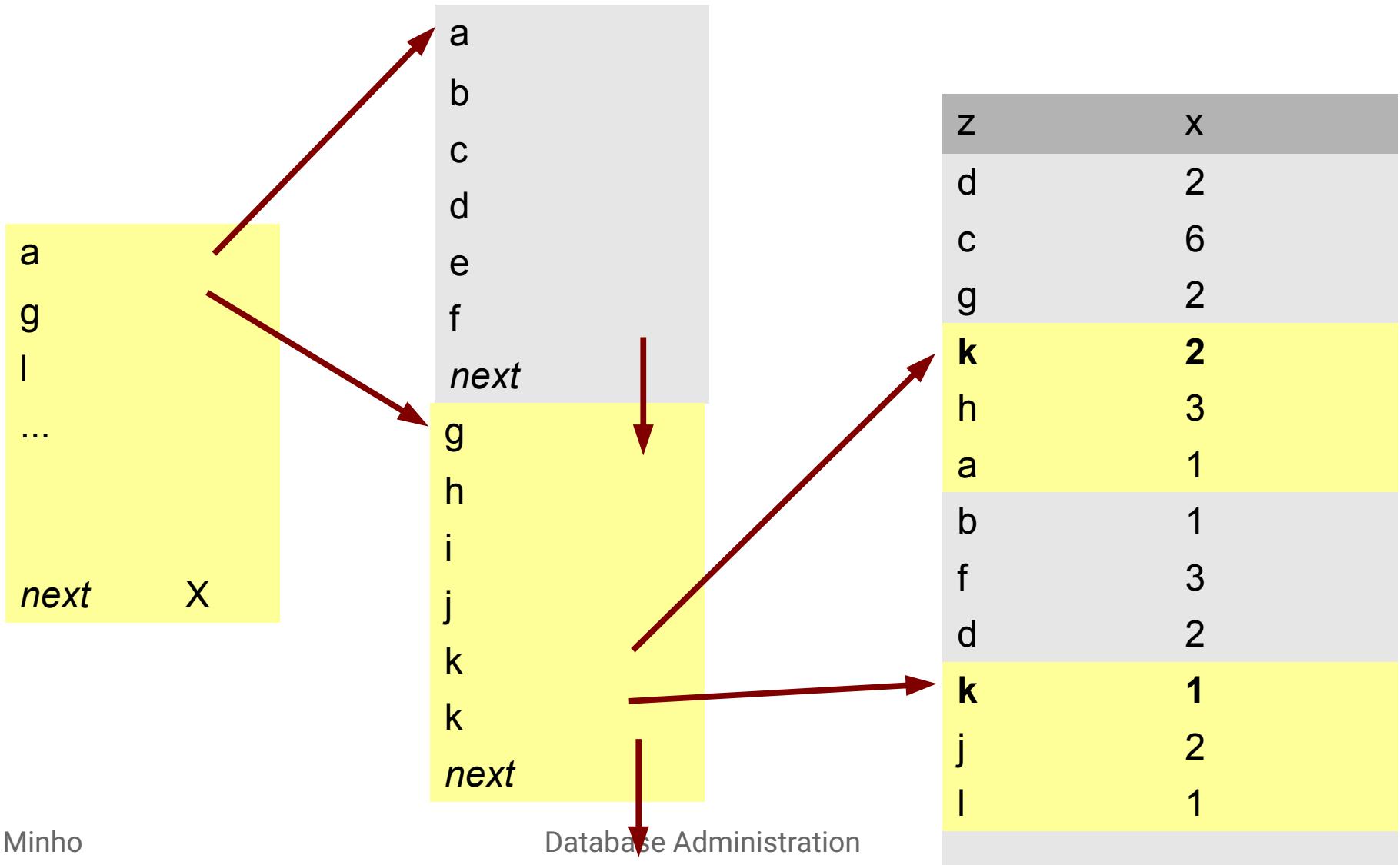
B-Tree

- Insert:
  - If free entry not available, split leaf
    - Recursively insert new leaf in upper layer
    - Tree grows towards the root!
  - Add entry to leaf

- Delete:
  - Remove entry from leaf
  - If enough space available, collapse leafs
   - Recursively delete leaf in upper layer

B-Tree

- Desirable characteristics:
  - Balanced
  - Log(n) depth
  - Fit for block I/O

- Supports:
  - Identity look up
  - Range queries / Ordered scan
  - Updates

Composite indexes

- Index on (X,Y):
  - Answers equality on (X,Y)
  - Answers equality and interval on X alone
  - Answers equality on X and interval on Y

- Index on expression, e.g. X+Y
 - Answers equality and interval on X+Y

Dispersion

a				
b				
c				
d				
e				
f				
next				

a
g
l
...
next X

g
h
i
k
k
k
next

z	x
d	2
c	6
g	2
k	**2**
h	3
k	**1**
b	1
f	3
d	2
k	**1**
j	2
l	1
...	...
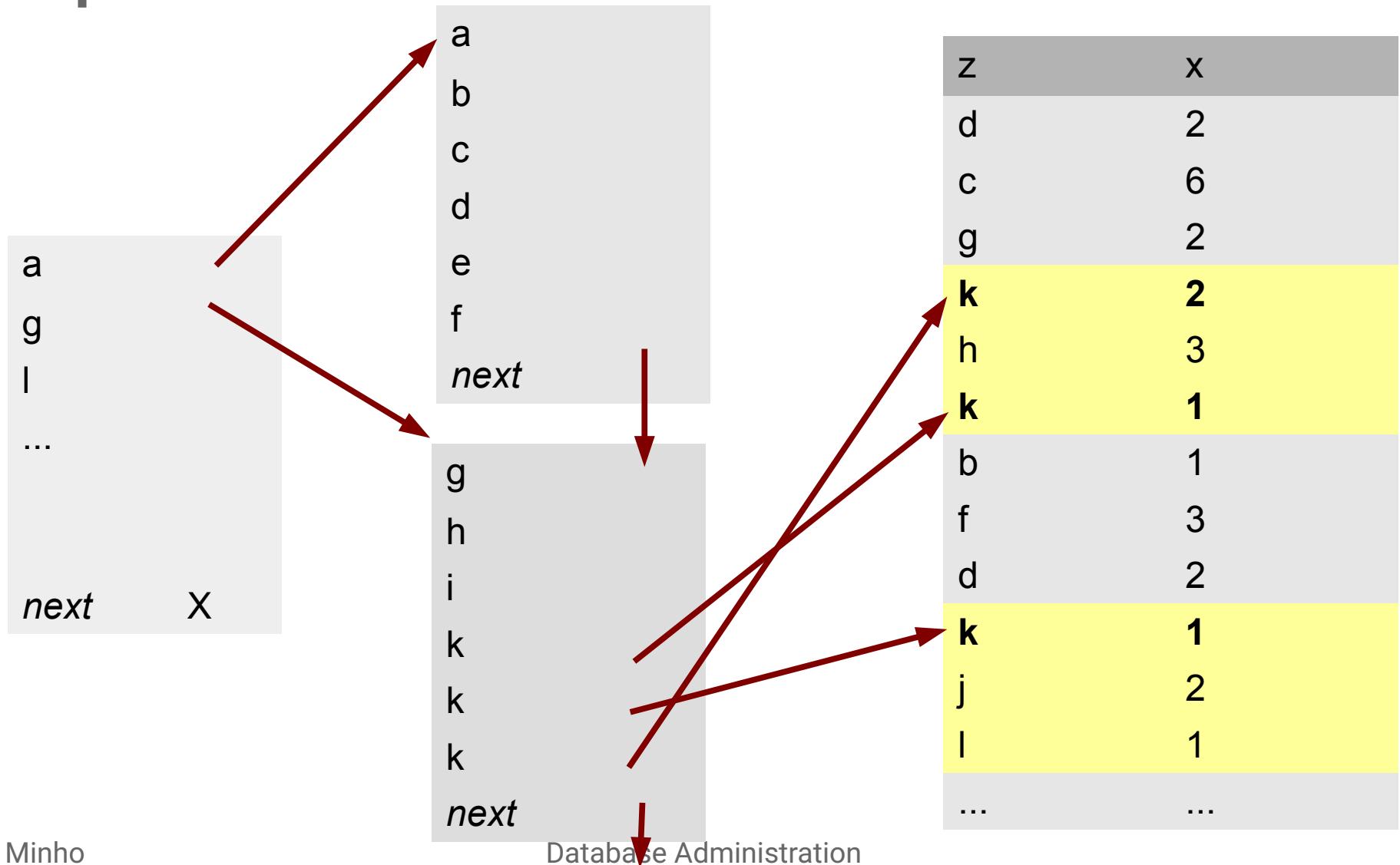
Clustered indexes

- Problem:
  - #blocks >> (#records / records per block)
  - Read each block multiple times

- A clustered index:
  - Records are (roughly) sorted according to the index
    - No sorting within a block is needed
  - Free space may be kept for insertions

Multi-criteria filtering

- Problem:
  - select x from Y
    where z = 'k'
    and x = 4;
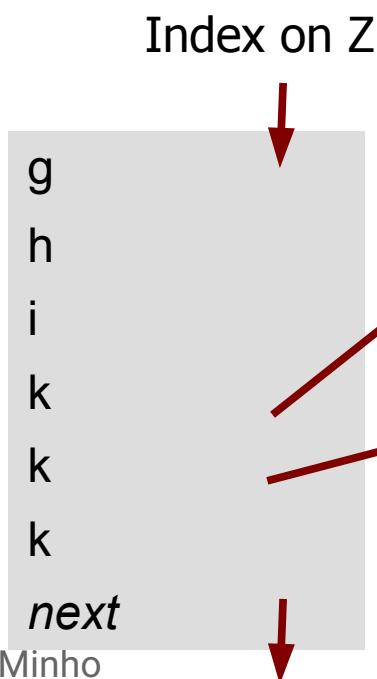
Index on Z

Z	X
d	2
c	6
g	**4**
h	2
h	3
k	**4**
b	1
f	3
d	2
k	1
j	2
l	1
...	...

Index on X

g
h
i
k
k
k
next

| |
|---|
| 1 |
| 2 |
| 3 |
| 4 |
| 4 |
| 5 |
| *next* |
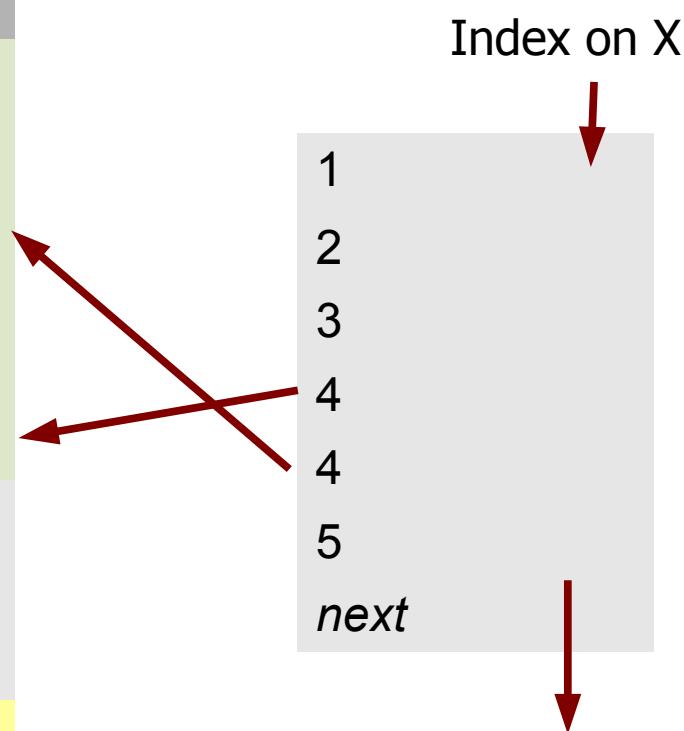
Multi-criteria filtering

- Sequential scan

- Either X or Z plus scan

- Composite index on (Z,X):
  - Often, many columns and combinations

- Typical examples:
  - Search with a combination of features
  - Hotel booking, real estate, on-line shopping, …

- What if "or" instead of "and"?
  - (T2 or T3) and in Braga

Bitmap indexes

- ## Step 1:
  - Build bitmap for each clause

Index on Z

g
h
i
k
k
k
next

Z='k'

0
0
0
0
0
0
1
0
0
0
1
0
0
...

X=4

0
0
1
0
0
1
0
0
0
0
0
0
...

Index on X

1
2
3
4
4
5
next
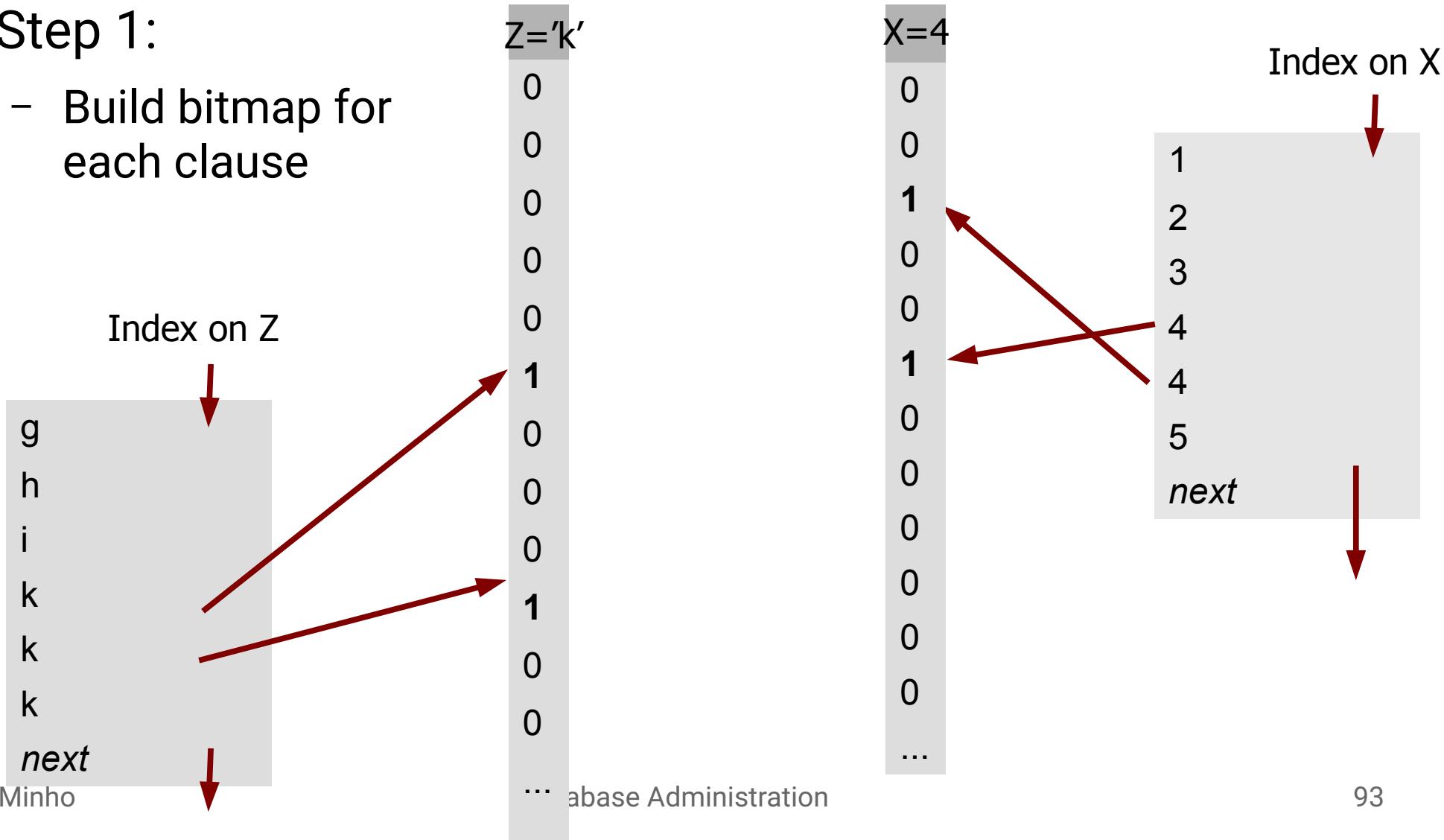
Bitmap indexes

- Step 2:
  - Combine with logical operators

Z='k'	... and ...	X=4
0	0	0
0	0	0
0	**0** ←	**1**
0	0	0
0	0	0
0	0	0
1 →	**1** ←	**1**
0	0	0
0	0	0
0	0	0
1 →	**0**	0
0	0	0
0	0	0
...	...	...
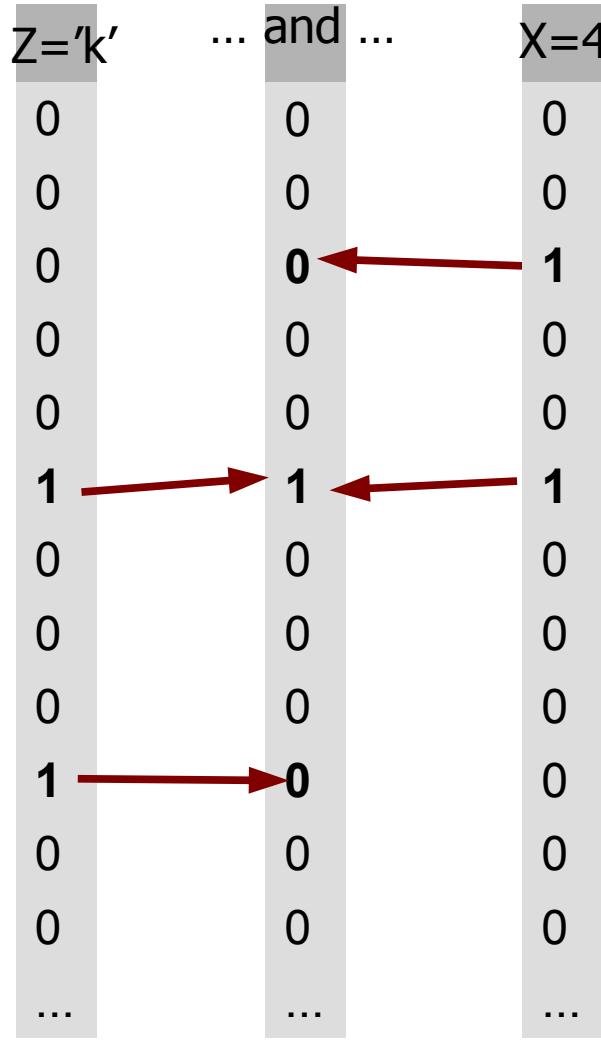
Bitmap indexes

- ## Step 3:
  - – Traverse bitmap and read table

... and ...	Z	X
0	d	2
0	c	6
0	g	**4**
0	h	2
0	h	3
1	**k**	**4**
0	b	1
0	f	3
0	d	2
0	**k**	1
0	j	2
0	l	1
...	...	...

Motivation

- Problem:

  select z from Y
  order by v <->

      (select v from Y where z='k')

  limit 10;

- Plan:

limit

↑

sort

↑

project v <-> subquery

↑

scan Y

- Cost?

z	v
d	[.9, ...]
c	[.6, ...]
g	[.7, ...]
k	**[.2, ...]**
h	**[.3, ...]**
a	[.4, ...]
b	[.5, ...]
f	**[.3, ...]**
d	[.5, ...]
x	**[.1, ...]**
j	[.9, ...]
l	[.8, ...]
...	...

Vector indexes

z	v
d	[.9, ...]
c	[.6, ...]
g	[.7, ...]
k	**[.2, ...]**
h	**[.3, ...]**
a	[.4, ...]
b	[.5, ...]
f	**[.3, ...]**
d	[.5, ...]
x	**[.1, ...]**
j	[.9, ...]
l	[.8, ...]
...	...

- Graph structure by proximity in multi-dimensional space:
  - Points to original rows
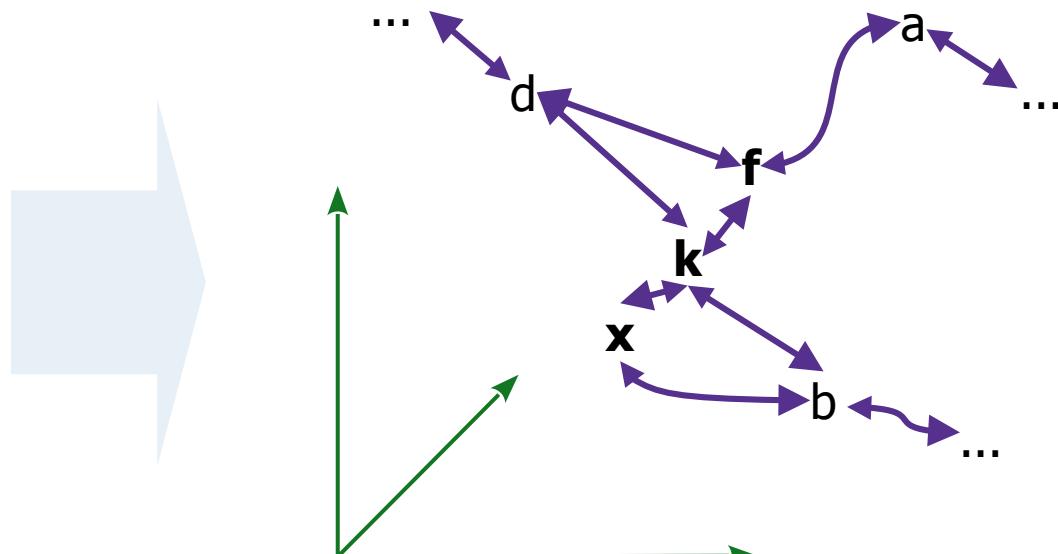
Vector indexes
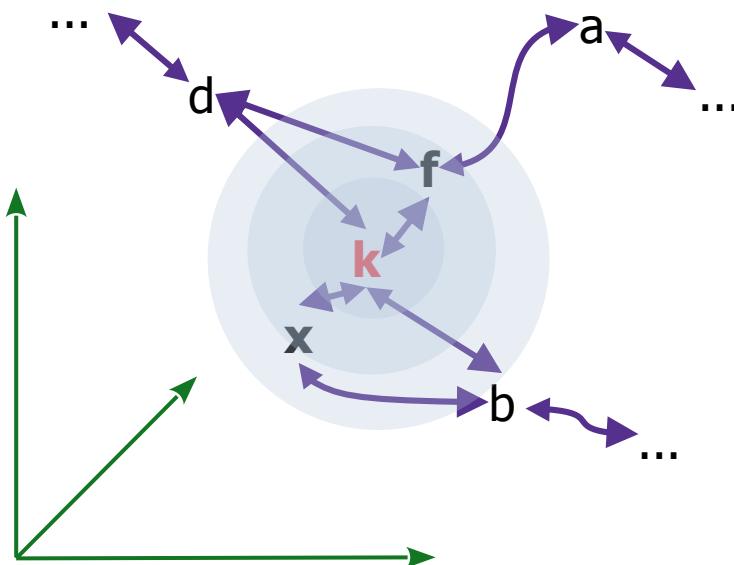
- Problem:

  select z from Y
  order by v <->

      (select v from Y where z='k')

  limit 10;

- Breadth-first traversal of graph from 'k' produces rows in increasing distance

- Simple plan:

  limit

  ↑

  index scan

Motivation

- Assumptions:
  - Several TB of data
  - ~50%, y=1
  - ~50%, y=2
  - a few, y=3

z	y
d	**1**
c	2
g	**1**
k	2
h	3
a	**1**
b	**1**
f	2
d	2
k	**1**
j	2
l	**1**
...	...

Motivation

- Problem:

  - select count(*) from X
    where y = 1;

- Possible plans:

count(*)

↑

select y = 1

↑

scan X

count(*)

↑

index scan X
(y = 1)
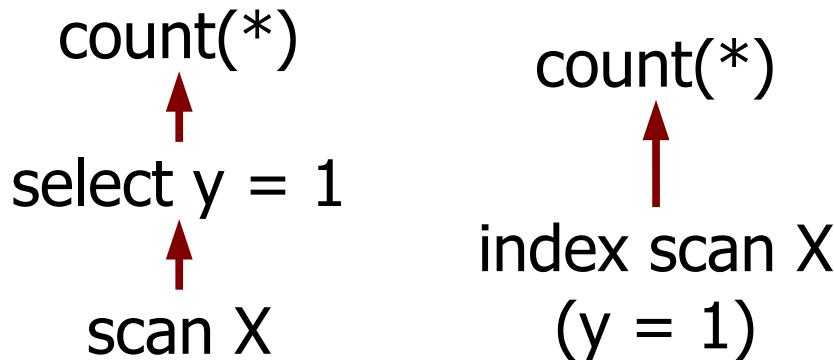
- Cost?

z	y
d	**1**
c	2
g	**1**
k	2
h	3
a	**1**
b	**1**
f	2
d	2
k	**1**
j	2
l	**1**
...	...

Motivation

- Keep results cached

- Update when needed

select y, count(*) from X group by y

y	count
1	**773647263**
2	765732332
3	1

X

z	y
d	**1**
c	2
g	**1**
k	2
h	3
a	**1**
b	**1**
f	2
d	2
k	**1**
j	2
l	**1**
...	...

Views

View
usage

select count(*) from V

count(*)

↑

V

View
definition

select y = 1

↑

scan X

create view V as select * from X where y=1

count(*)

↑

select y = 1

↑

scan X

Plan
executed

Materialized views

View usage
$\left\{\vphantom{\begin{array}{c}a\\b\\c\\d\end{array}}\right.$

select count(*) from V

count(*)

↑

V

$\left.\vphantom{\begin{array}{c}a\\b\\c\\d\end{array}}\right\}$ Plan executed

View definition
$\left\{\vphantom{\begin{array}{c}a\\b\\c\\d\end{array}}\right.$

materialize V

↑

select y = 1

↑

scan X

create materialized view V as select * from X where y=1
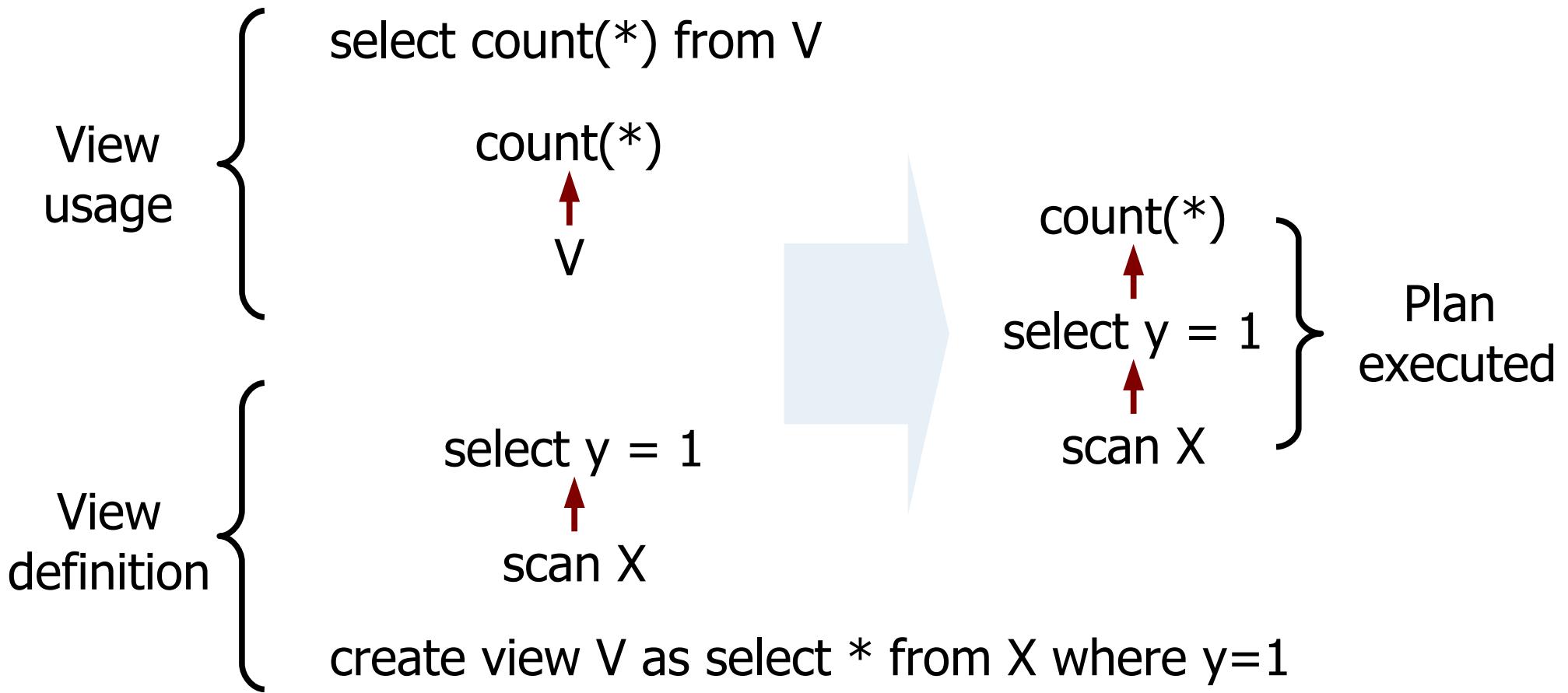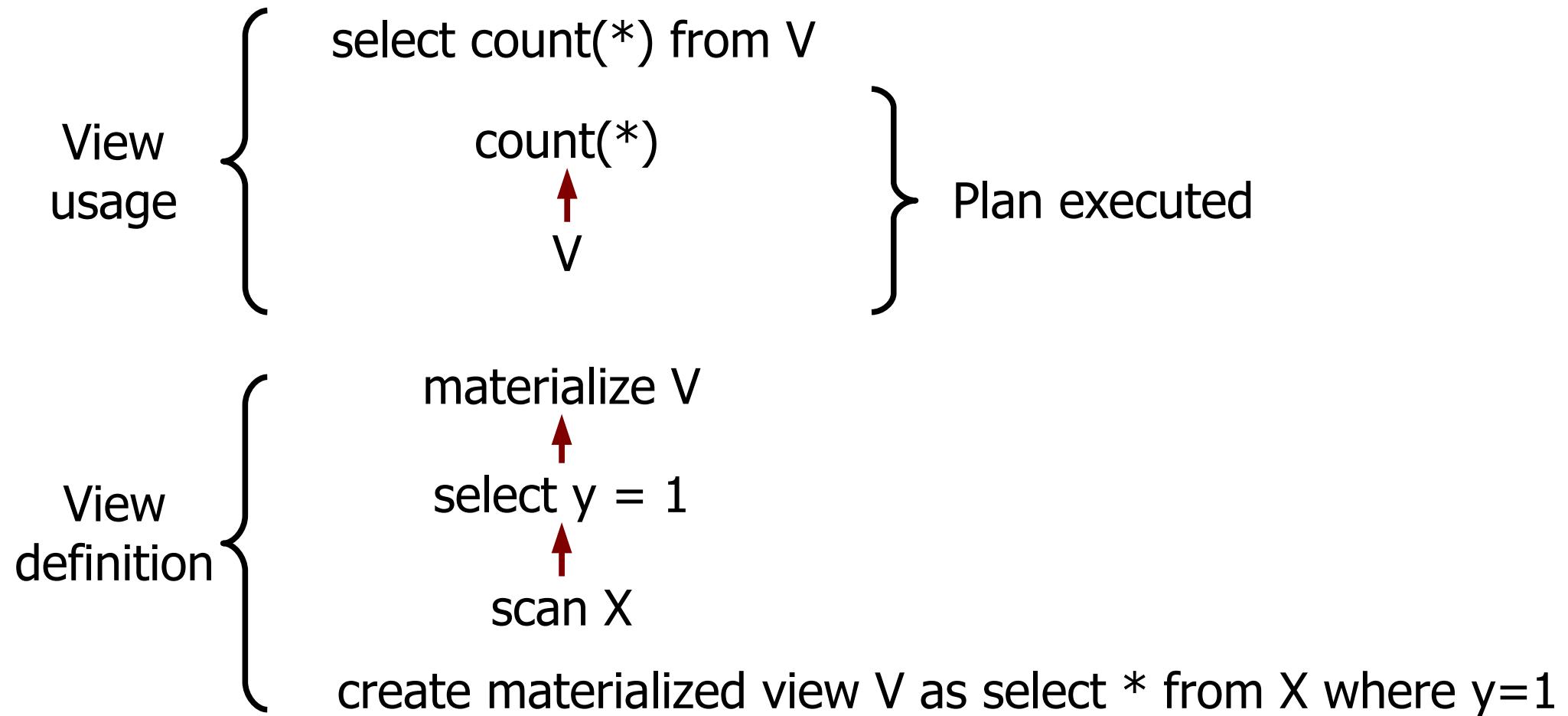
Maintaining materialized views

- Periodically run the query and update the view

- Update the view when data changes

DIY Materialized Views

- Updating with AFTER triggers:

```
-- Create view
select sum(value) into mv_sum_items from items;

-- Update view
create function upd_sum_items() returns trigger as '
    BEGIN
        update mv_sum_items set sum = sum + new.value - old.value;
        return new;
    END
' language 'plpgsql';

create trigger upd_sum
    after update on items
    for each row execute procedure upd_sum_items();
```

Using materialized views

- Automatically used by the planner:
  - Indexed views in MS SQL Server
- Used explicitly in queries:
  - Materialized views in Oracle
  - DIY materialized views everywhere
  - Developer tip:
    - Using views allows the DBA to select which ones to materialize

Conclusions

- Indexes and mat. views = Redundancy!

- Trade-off between:

  - Complexity of operations

  and:

  - Disk space used

  - Usage of main memory

  - Effort when updating

- Usefulness depends on workload mix