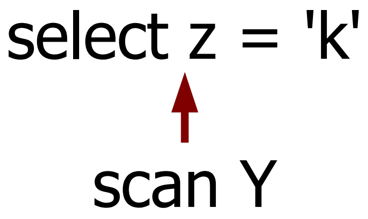
Database Administration

José Orlando Pereira

Departamento de Informática
Universidade do Minho

Motivation

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



select z = 'k'

scan Y

- Cost?

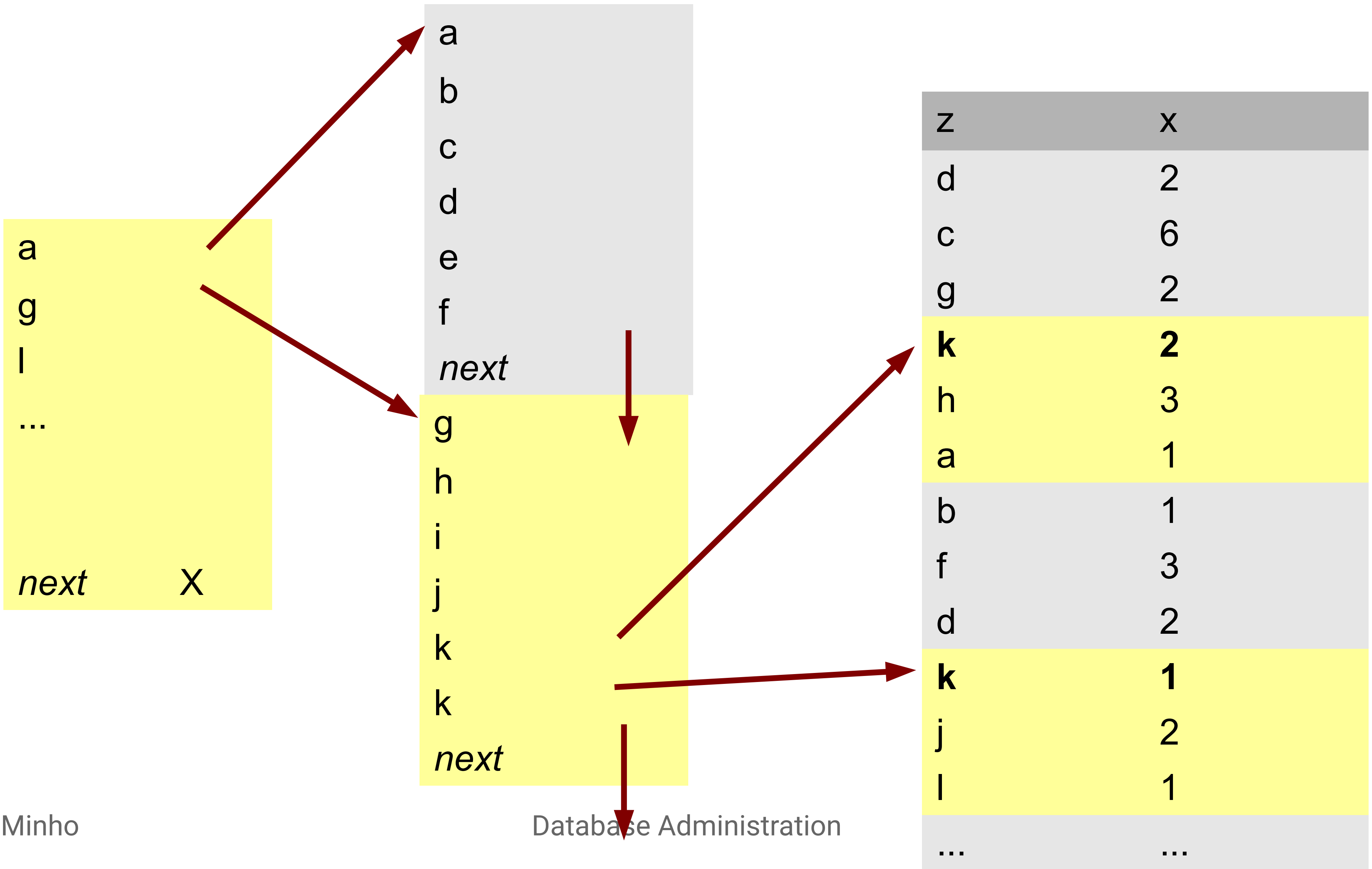
z	x
d	2
c	6
g	2
k	**2**
h	3
a	1
b	1
f	3
d	2
k	**1**
j	2
l	1
...	...

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
g
l
…
next X

a
b
c
d
e
f
next

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

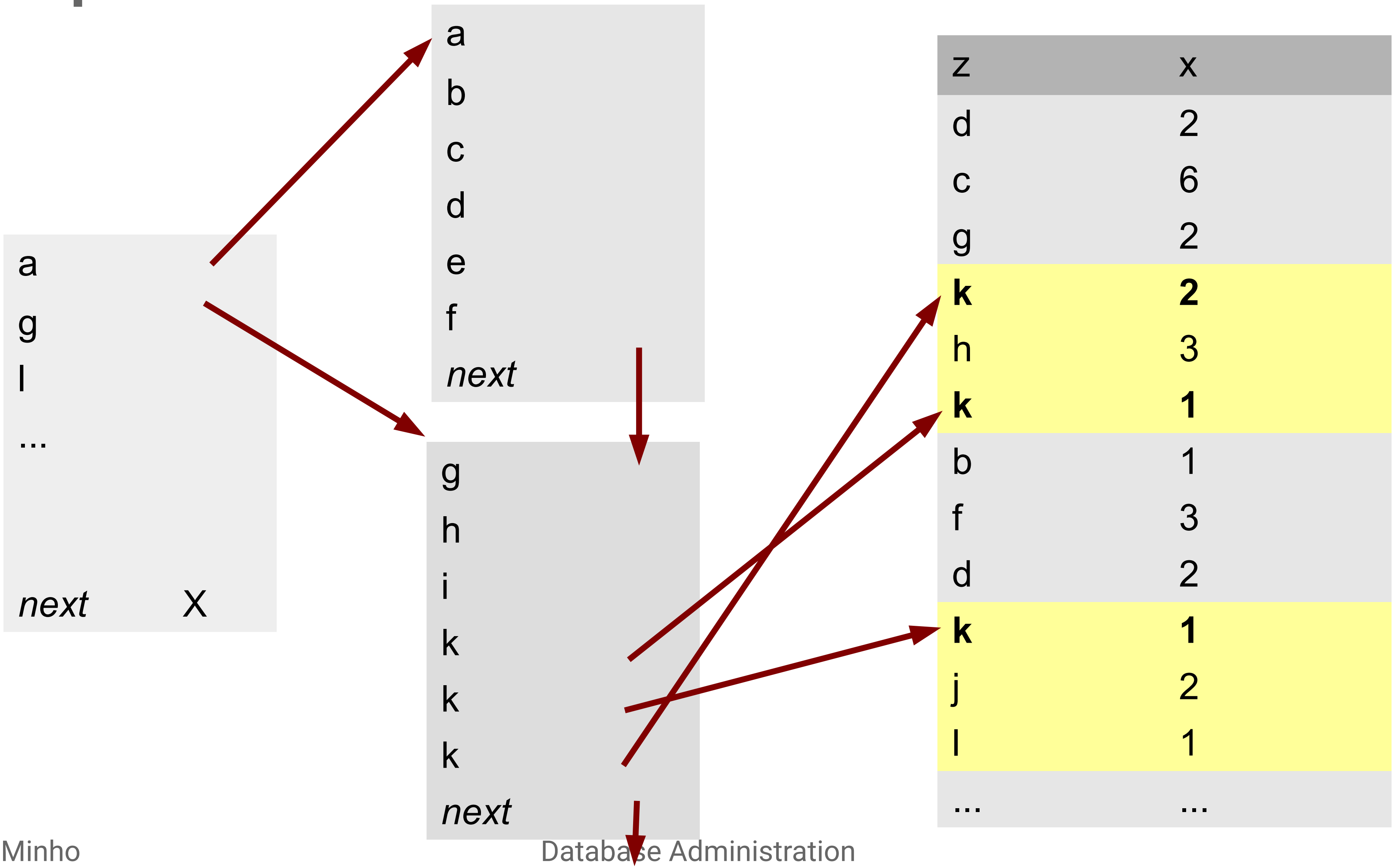
B-Tree

- 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

g

l

...

next X

a

b

c

d

e

f

next

g

h

i

k

k

k

next

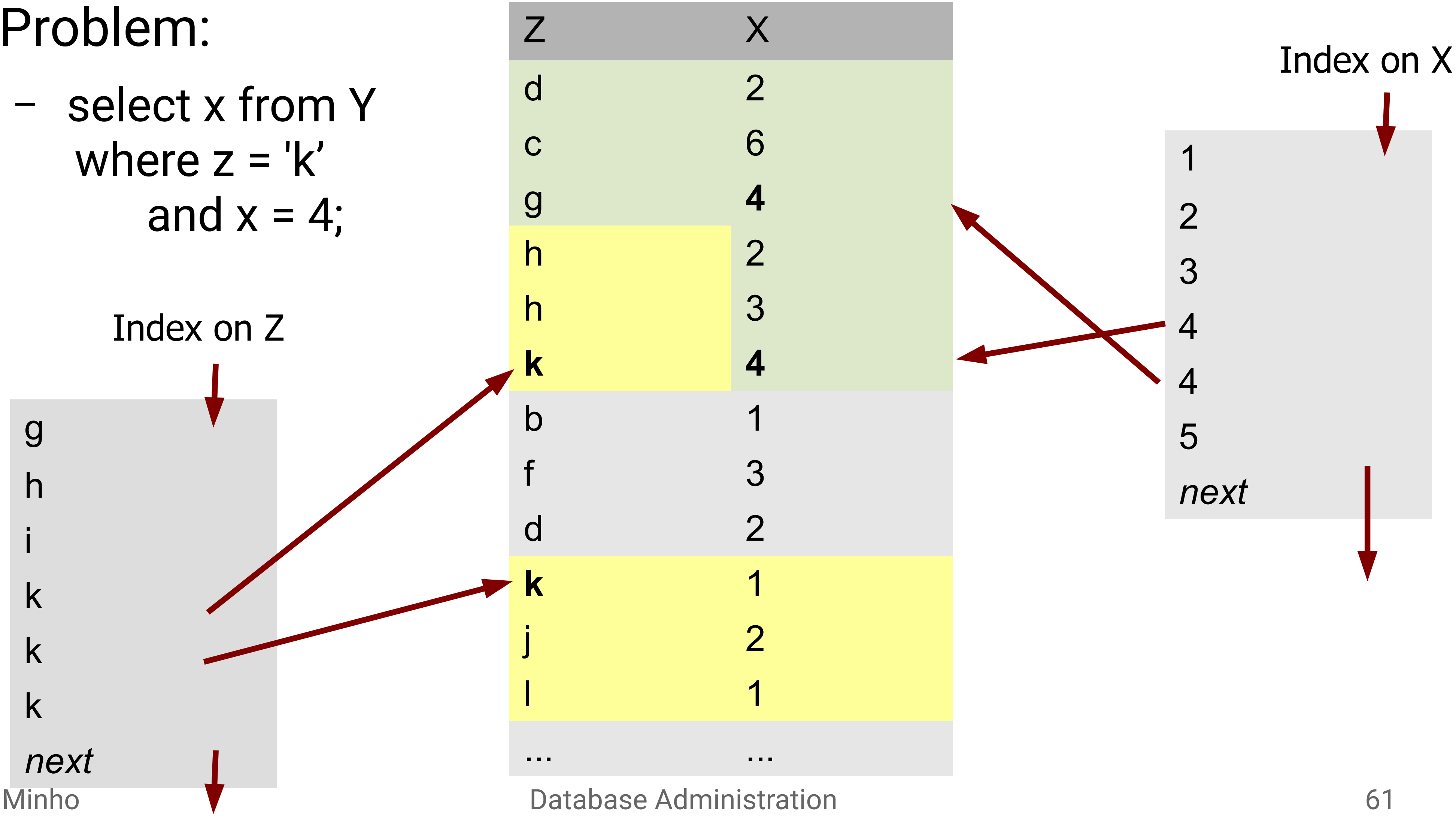
z	x
d	2
c	6
g	2
k	**2**
h	3
k	**1**
b	1
f	3
d	2
k	**1**
j	2
l	1
...	...

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

g
h
i
k
k
k
next

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

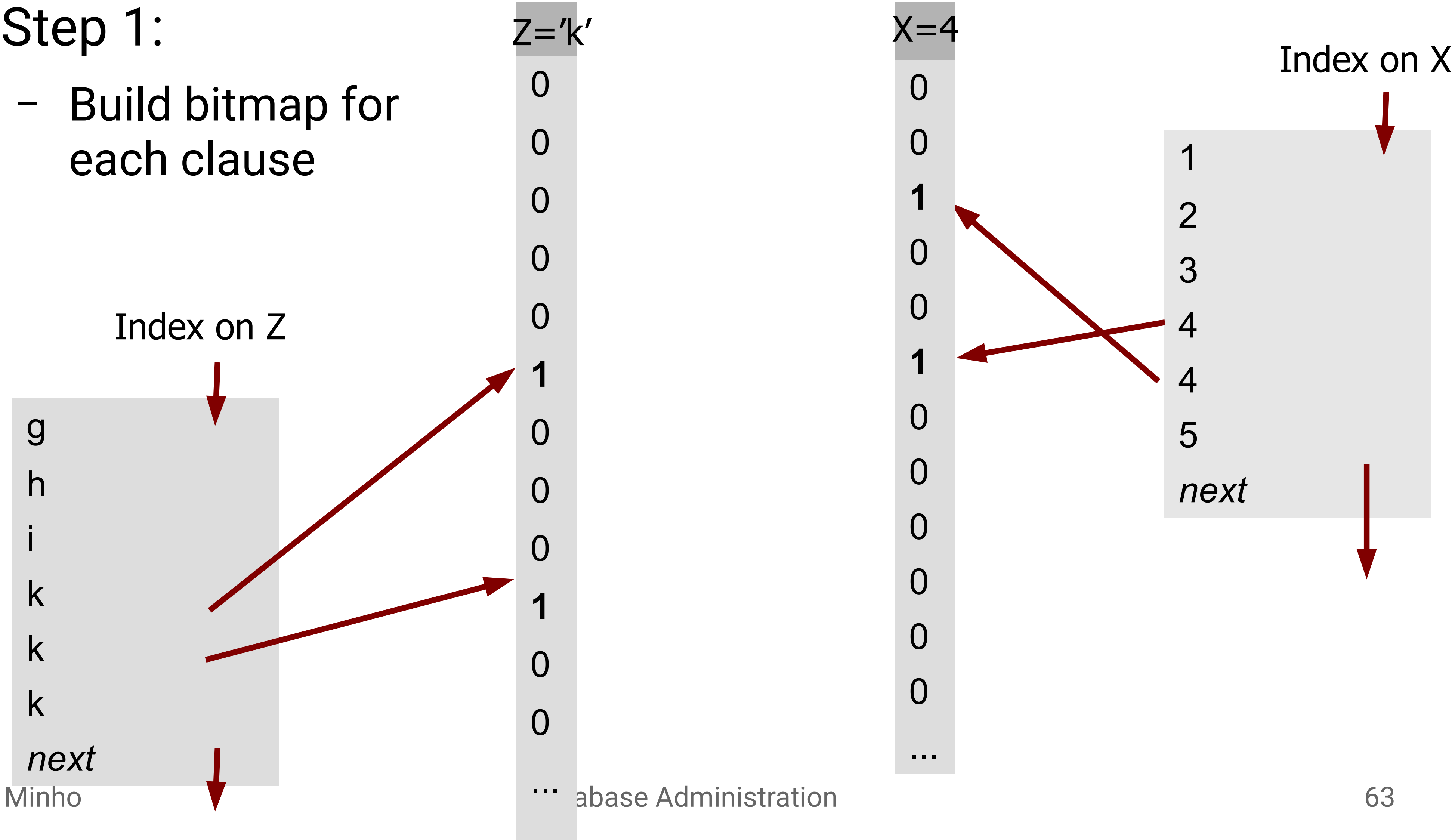
1
2
3
4
4
5
next

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

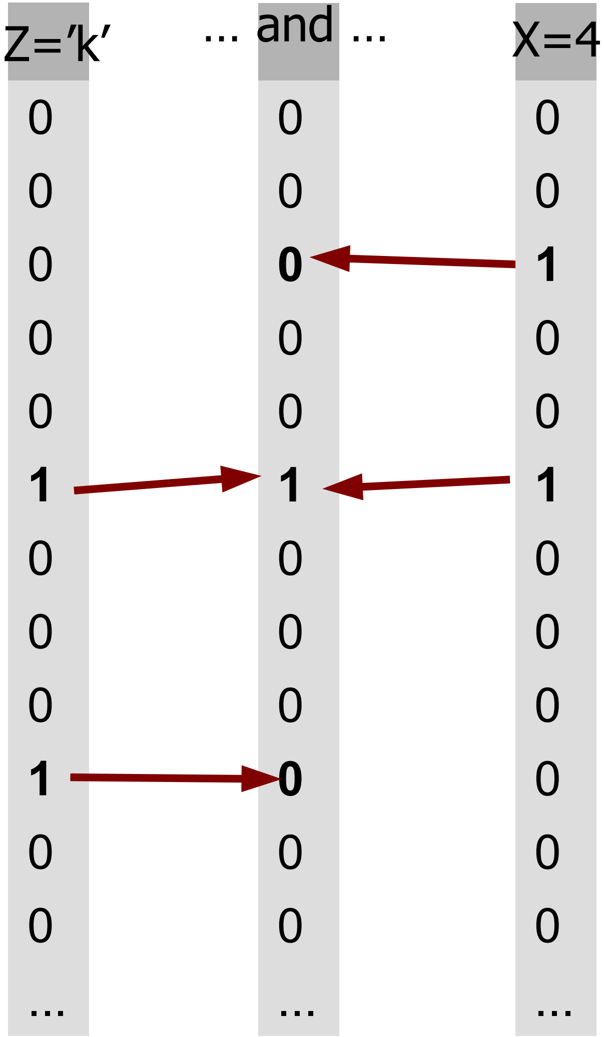
Bitmap indexes

- Step 1:
  - Build bitmap for each clause



Bitmap indexes

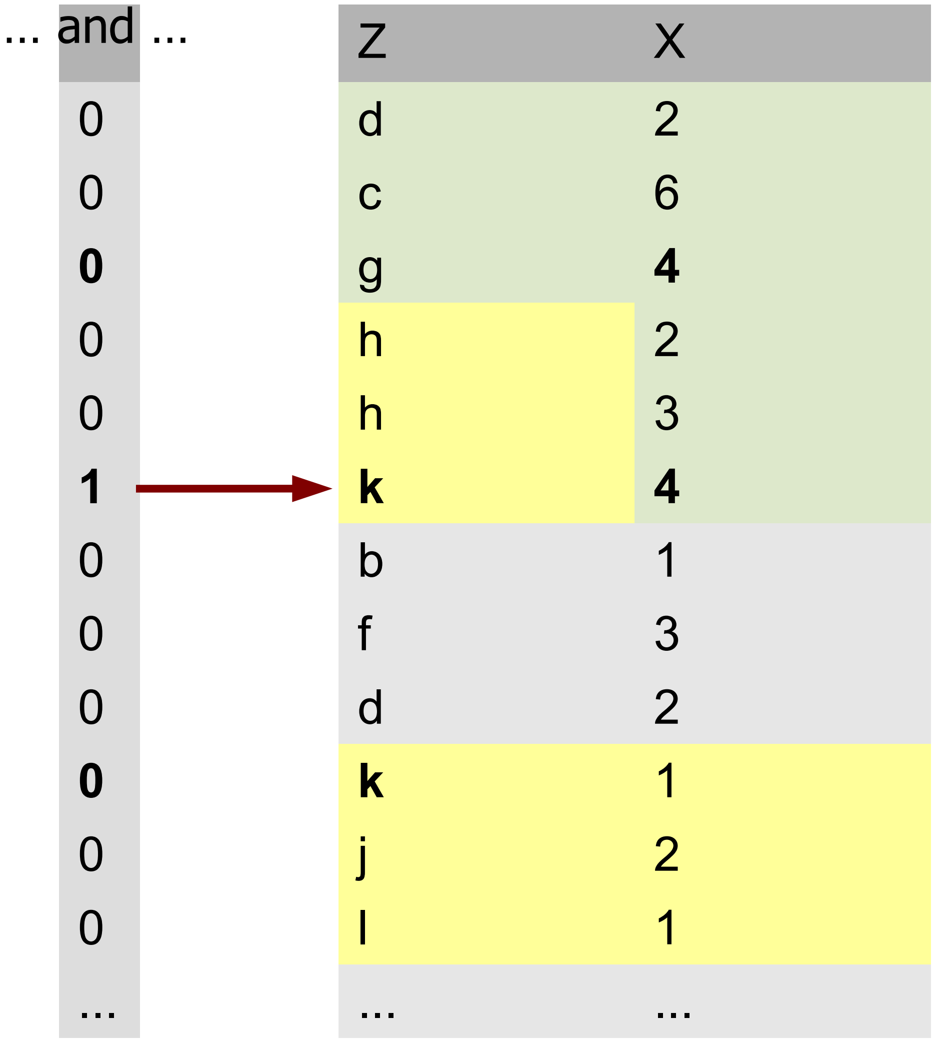
- Step 2:
  - Combine with logical operators



Z=′k′	… and …	X=4
0	0	0
0	0	0
0	**0**	**1**
0	0	0
0	0	0
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



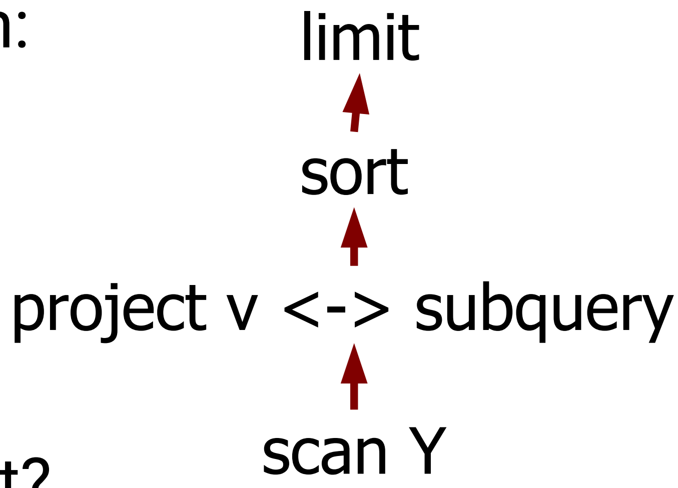
... and ...	Z	X
0	d	2
0	c	6
0	g	**4**
0	h	2
0	h	3
1	**k**	**4**
0	b	1
0	f	3
0	d	2
0	**k**	1
0	j	2
0	l	1
...	...	...

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

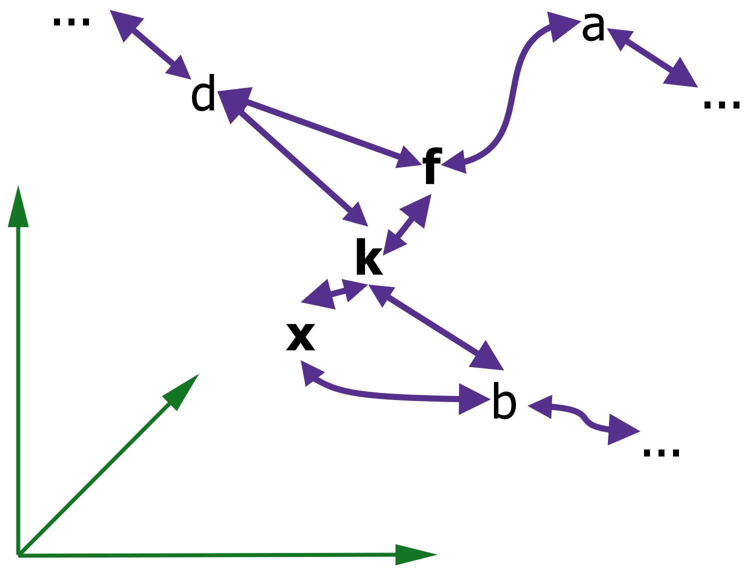
- Cost?

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, ...]
...	...

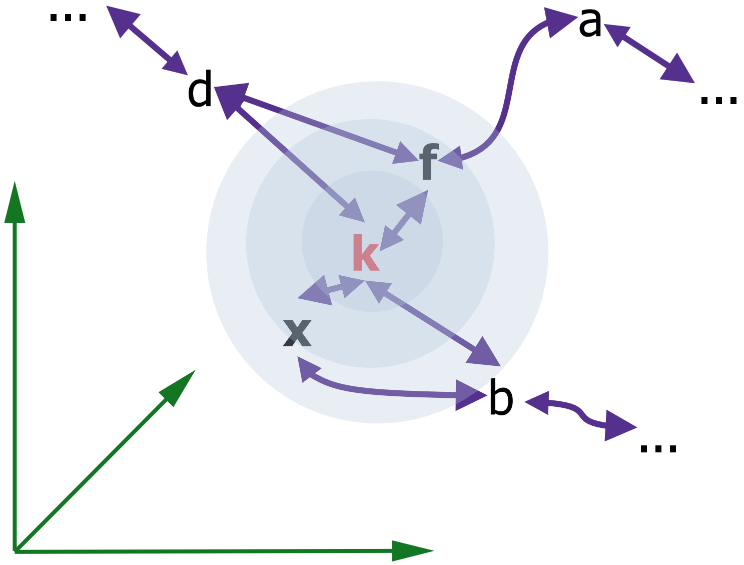
Vector indexes

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



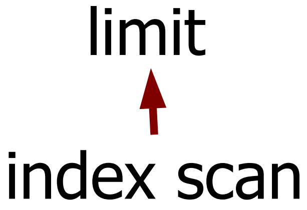
Vector indexes



- 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

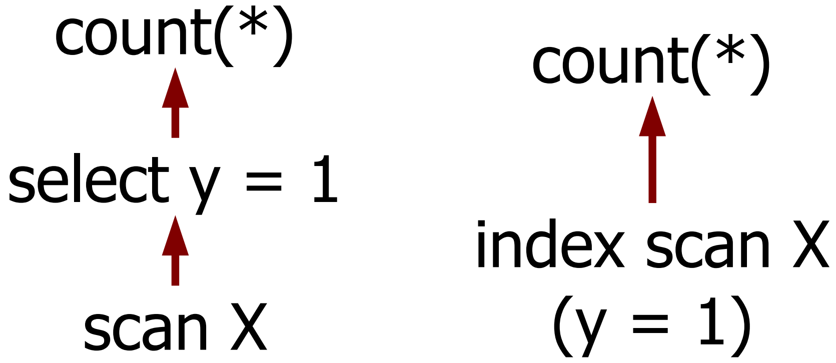
Motivation

- 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

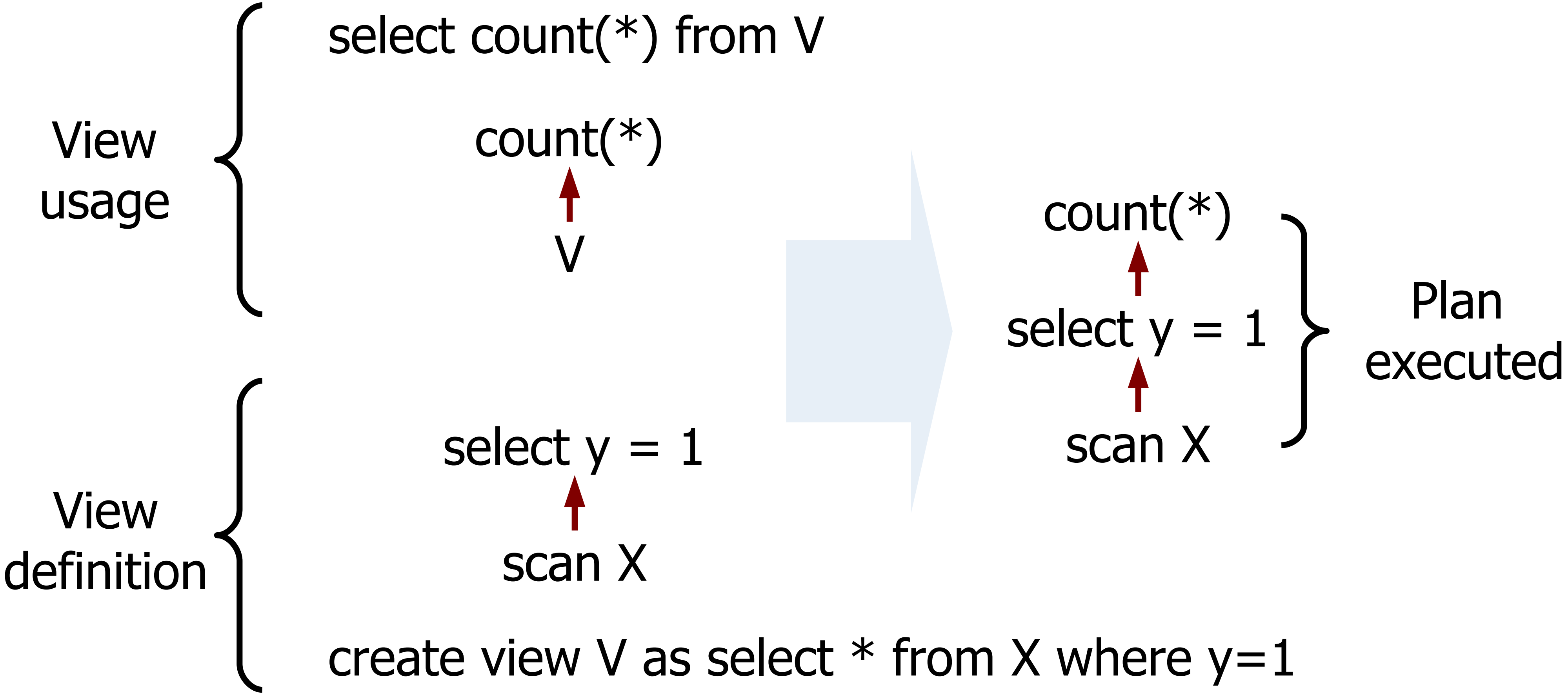
select y, count(*) from X group by y

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

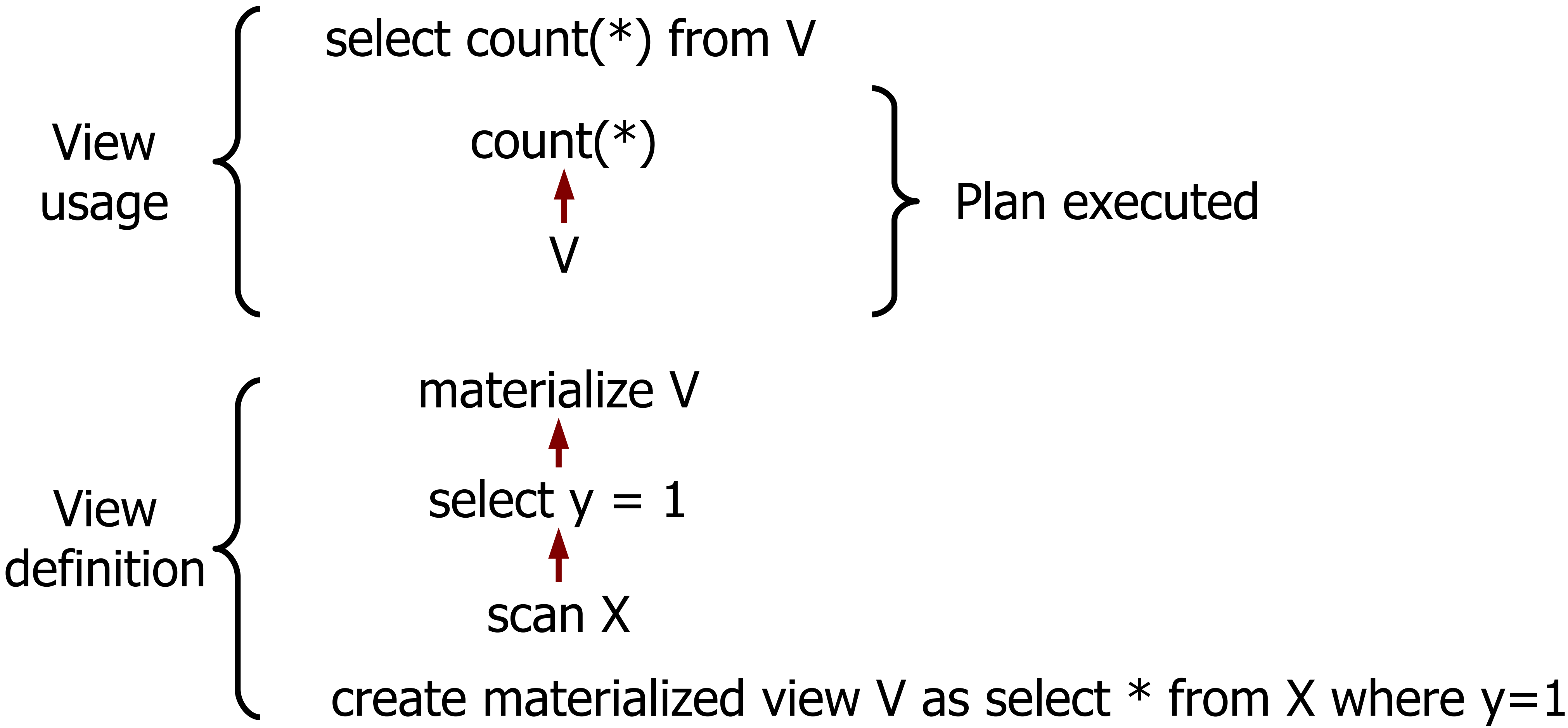
count(*)

select y = 1

scan X

Plan executed

Materialized views



View usage

select count(*) from V

count(*)

V

Plan executed

View definition

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