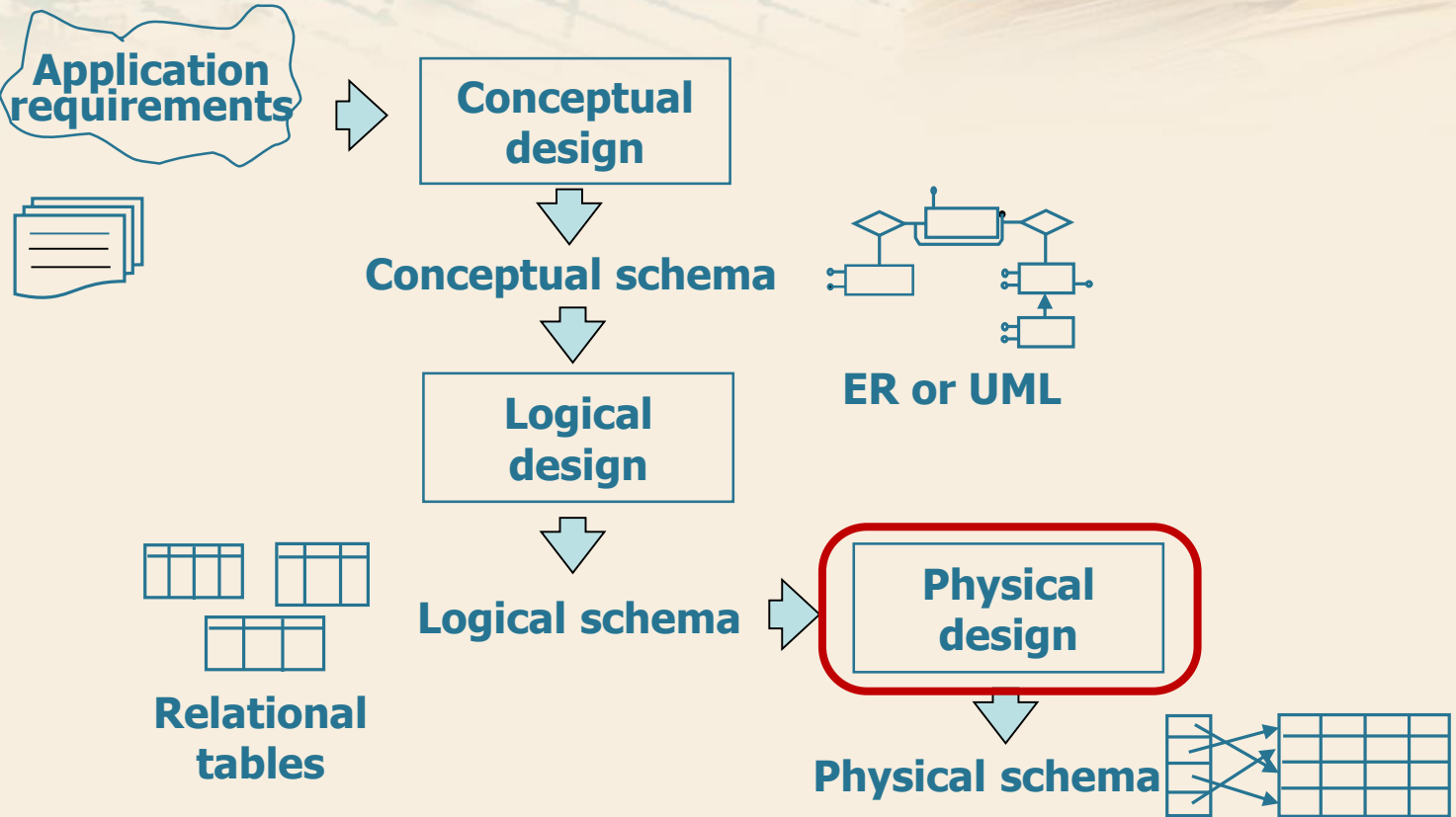




Database Management Systems

Physical Design

Phases of database design



➤ Goal

- Providing good performance for database applications

➤ Application software is not affected by physical design choices

- Data independence

➤ It requires the selection of the DBMS product

- Different DBMS products provide different
 - storage structures
 - access techniques

Physical design: Inputs

- Logical schema of the database
- Features of the selected DBMS product
 - e.g., index types, page clustering
- Workload
 - Important queries with their estimated frequency
 - Update operations with their estimated frequency
 - Required performance for relevant queries and updates

Physical design: Outputs

- Physical schema of the database
 - table organization, indices
- Set up parameters for database storage and DBMS configuration
 - e.g., initial file size, extensions, initial free space, buffer size, page size
 - Default values are provided


Physical design: Selection dimensions

➤ Physical file organization

- unordered (heap)
- ordered (clustered)
- hashing on a hash-key
- clustering of several relations
 - Tuples belonging to different tables may be interleaved

Physical design: Selection dimensions

➤ Indices

- different structures
 - e.g., B⁺-Tree, hash
- clustered (or primary) 
 - *Only one* index of this type can be defined
- unclustered (or secondary)
 - *Many* different indices can be defined

Characterization of the workload

➤ For each query

- accessed tables
- visualized attributes
- attributes involved in selections and joins
- selectivity of selections

➤ For each update

- attributes and tables involved in selections
- selectivity of selections
- update type (Insert / Delete / Update) and updated attributes (if any)

Selection of data structures

- Selection of
 - physical storage of tables
 - indices
- For each table
 - file structure
 - heap or clustered
 - attributes to be indexed
 - hash or B⁺-Tree
 - clustered or unclustered

Selection of data structures

➤ Changes in the logical schema

- alternatives which preserve BCNF (Boyce Codd Normal Form)
- alternatives *not* preserving BCNF
 - e.g., in data warehouses
- partitioning on different disks

Physical design strategies


- No general design methodology is available
 - trial and error design process
 - general criteria
 - “common sense” heuristics
- Physical design may be improved after deployment
 - database tuning


General criteria

- The primary key is usually exploited for selections and joins
 - index on the primary key
 - clustered or unclustered, depending on other design constraints

➤ Add more indices for the most common query predicates

- Select a frequent query
- Consider its current evaluation plan
- Define a new index and consider the new evaluation plan
 - if the cost improves, add the index
- Verify the effect of the new index on
 - modification workload
 - available disk space

- Never index *small* tables
 - loading the entire table requires few disk reads
- Never index attributes with *low cardinality domains*
 - low selectivity 
 - e.g., gender attribute
 - not true in data warehouses
 - different workloads and exploitation of bitmap indices

- For attributes involved in *simple predicates* of a where clause
 - Equality predicate
 - Hash is preferred 
 - B⁺-Tree
 - Range predicate
 - B⁺-Tree
- Evaluate if using a clustered index improves in case of slow queries

- For where clauses involving *many* simple predicates
 - Multi attribute (composite) index
 - Select the appropriate key order
 - the order of attributes affects the usability of the index
- Evaluate maintenance cost

➤ To improve *joins*

- Nested loop
 - Index on the *inner* table join attribute
- Merge scan
 - B⁺-Tree on the join attribute (if possible, clustered)

➤ For *group by*

- Index on the grouping attributes
 - Hash index or B⁺-tree

➤ Consider *group by push down*

- anticipation of group by with respect to joins
- not available in all systems
 - observe the execution plan

Example: Group by push down

➤ Tables

PRODUCT (Prod#, PName, PType, PCategory)

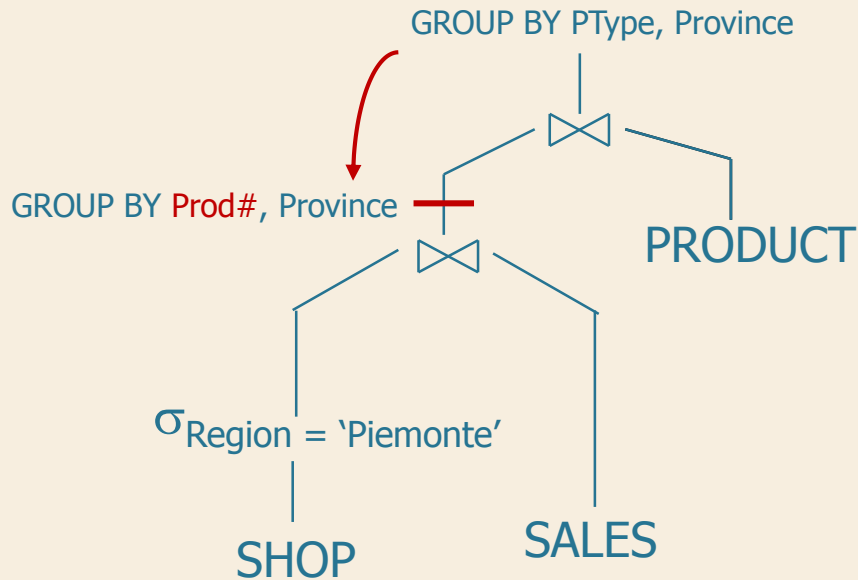
SHOP (Shop#, City, Province, Region, State)

SALES (Prod#, Shop#, Date, Qty)

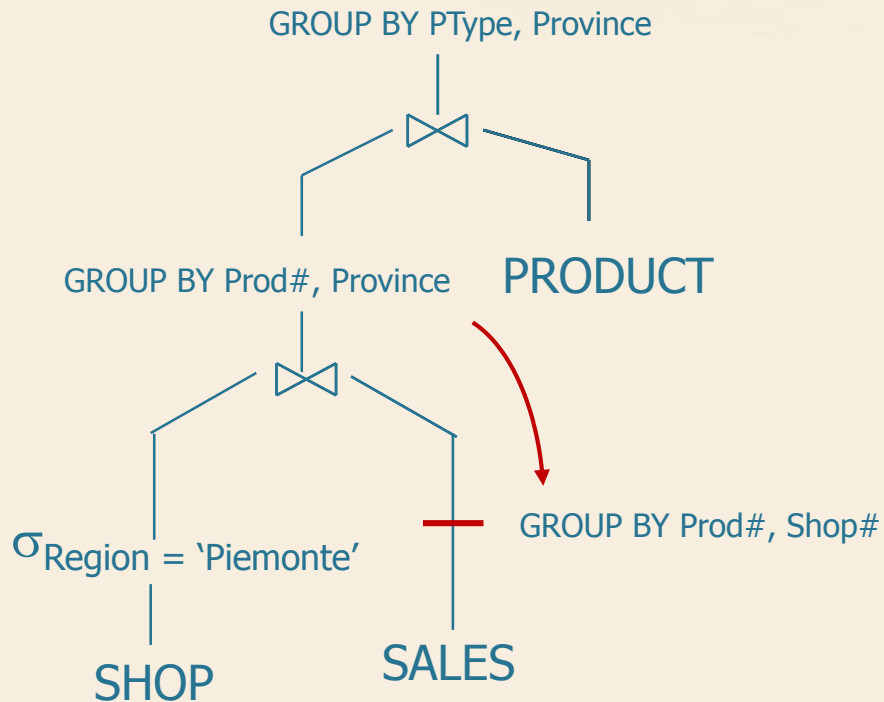
➤ SQL query

```
SELECT PType, Province, SUM (Qty)
FROM Sales S, Shop SH, Product P
WHERE S.Shop# = SH.Shop#
AND S.Prod# = P.Prod#
AND Region = 'Piemonte'
GROUP BY PType, Province;
```

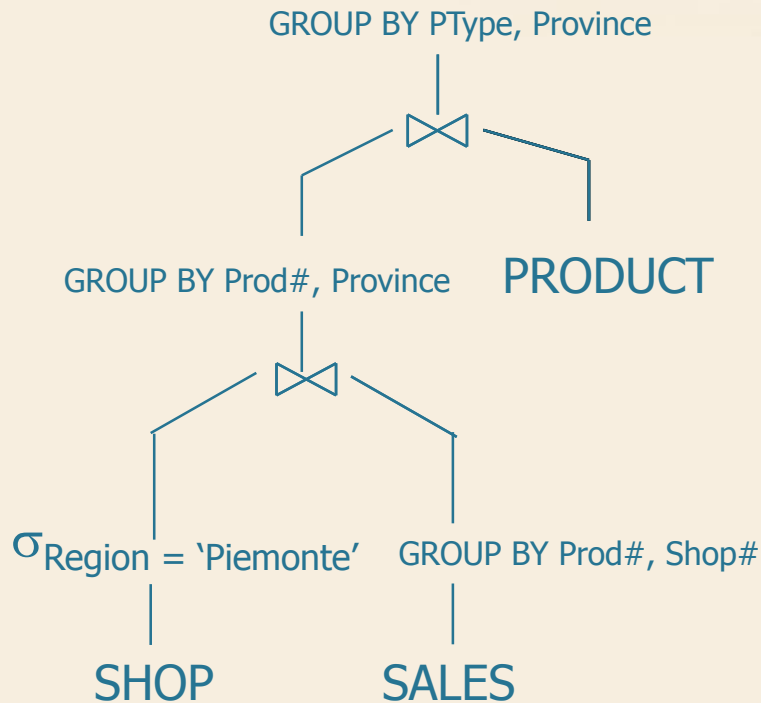
Example: Initial query tree



Example: Rewritten query tree (1)



Example: Rewritten query tree (2)



If it does not work?

- Query execution is not as fast as you expect
 - or you are not satisfied yet
- Remember to update database statistics!
- Database tuning
 - Add and remove indices
 - May be performed also after deployment
- Techniques to affect the optimizer decision
 - Should almost *never* be used
 - called hints in oracle
 - Data independence is *lost*



Database Management Systems

Physical Design Examples

Example tables

➤ Tables

- EMP (Emp#, EName, Dept#, Salary, Age, Hobby)
- DEPT (Dept#, DName, Mgr)
 - In EMP
Dept# FOREIGN KEY REFERENCES DEPT.Dept#
 - In DEPT
Mgr FOREIGN KEY REFERENCES EMP.Emp#

Example 1

➤ SQL query

```
SELECT *  
FROM EMP  
WHERE Salary/12 = 1500;
```

➤ Index on the salary attribute (B⁺-Tree)

- The index may be disregarded because of the arithmetic expression

Example 2

➤ SQL query

```
SELECT *  
FROM EMP  
WHERE Salary = 18000;
```

➤ The index is used but it does not provide any benefit

- Consider Salary data distribution
 - The value is very frequent and index access is not appropriate 💬

Example 3

➤ Suppose that table EMP has block factor (number of tuples per block) equal to 30

a) $\text{Card}(\text{DEPT}) = 50$

b) $\text{Card}(\text{DEPT}) = 2000$

For accessing Dept# in the EMP table, would you define a secondary index on Emp.Dept#?

Example 3

➤ Case A: $\text{Card}(\text{DEPT}) = 50$

- Indexing is *not* appropriate
- Each page on average contains almost all departments
 - sequential scan is better

➤ Case B: $\text{Card}(\text{DEPT}) = 2000$

- Indexing is appropriate
- Each page contains tuples belonging to few departments

Example 4

➤ SQL query

```
SELECT EName, Mgr  
FROM   EMP E, DEPT D  
WHERE  E.Dept# = D.Dept#  
AND    DName = 'Toys';
```

➤ Index definition

- Hash Index on DName for the selection condition
- Hash Index on Emp. Dept# for a nested loop with Emp as *inner* table

Example 5

➤ SQL query

```
SELECT EName, Mgr  
FROM   EMP E, DEPT D  
WHERE  E.Dept# = D.Dept#  
AND    DName = 'Toys'  
AND    Age=25;
```

➤ Index definition

- An index on Age may be considered
 - it depends on the selectivity of the condition

Example 6

⇒ SQL query

```
SELECT EName, Mgr  
FROM   EMP E, DEPT D  
WHERE  E.Dept# = D.Dept#  
AND Salary BETWEEN 10000 AND 12000  
AND Hobby='Tennis';
```

Example 6: selection

- Alternatives for the selection on EMP
 - hash index on Hobby
 - B⁺-Tree on Salary
- Usually equality predicates are more selective
- One index is always considered by the optimizer
- Two indices may be exploited by smart optimizers
 - compute the intersection of RIDs before reading tuples

Example 6: join

➤ Alternatives for join

- Hash join
- Nested loop
 - EMP outer
 - because of selection predicates
 - DEPT inner
 - plus index on DEPT.Dept#
not appropriate if DEPT table is very small

Example 7

➤ SQL query

```
SELECT Dept#, Count(*)  
FROM EMP  
WHERE Age>20  
GROUP BY Dept#
```

Example 7

- If the selection condition on Age is not very selective
 - *no* B⁺-Tree on Age
- For group by
 - Clustered index on Dept#
 - Avoids sorting and reads blocks ready for group by
 - Good!
 - Secondary index on Dept#
 - May cause too many reads
 - Consider if appropriate

Example 8

⇒ SQL query

```
SELECT Dept#, COUNT(*)  
FROM EMP  
GROUP BY Dept#
```

Example 8

- Unclustered (secondary) index on Dept#
 - It avoids reading table EMP
- It is a *covering index*
 - it answers the query without requiring access to table data

Example 9

➤ SQL query

```
SELECT Mgr  
FROM   DEPT, EMP  
WHERE  DEPT.Dept# = EMP.Dept#
```

➤ Unclustered index on EMP.Dept#

- It avoids reading table EMP

Example 10

⇒ SQL query

```
SELECT AVG(Salary)
FROM EMP
WHERE Age = 25
AND Salary BETWEEN 3000 AND 5000
```

Example 10

➤ Composite index on <Age,Salary>

- Fastest solution
- This order is the best if the condition on Age is more selective

➤ Issues in composite indices

- Order of the fields in a composite index is important
- Update overhead grows