

Physical Database Design and Tuning

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Introduction to Database Management
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Physical Database Design and Tuning

Physical Design The process of selecting a physical schema (collection of data structures) to implement the conceptual schema

Tuning Periodically adjusting the physical and/or conceptual schema of a working system to adapt to changing requirements and/or performance characteristics

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Good design and tuning requires understanding the database workload.

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- the most important queries and their frequency
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 - Which relations are accessed?
 - Which attributes are retrieved?
 - Which attributes occur in selection/join conditions? How *selective* is each condition?
 - For each update:
 - Type of update and relations/attributes affected.
 - Which attributes occur in selection/join conditions? How *selective* is each condition?

The Physical Schema

- A storage strategy is chosen for each relation
 - Possible storage options:
 - Unsorted (heap) file
 - Sorted file
 - Hash file
- Indexes are then added
 - Speed up queries
 - Extra update overhead
 - Possible index types:
 - B-trees (actually, B+-trees)
 - R trees
 - Hash tables
 - ISAM, VSAM
 - ...

A Table Scan

```
select *  
from Employee  
where Lastname = 'Smith'
```

- To answer this query, the DBMS must search the blocks of the database file to check for matching tuples.
- If no indexes exist for Lastname (and the file is unsorted with respect to Lastname), all blocks of the file must be scanned.

Creating Indexes

```
create index LastnameIndex  
on Employee(Lastname) [CLUSTER]
```

```
drop index LastnameIndex
```

Primary effects of LastnameIndex:

- Substantially reduce execution time for selections that specify conditions involving Lastname
- Increase execution time for insertions
- Increase or decrease execution time for updates or deletions of tuples from Employee
- Increase the amount of space required to represent Employee

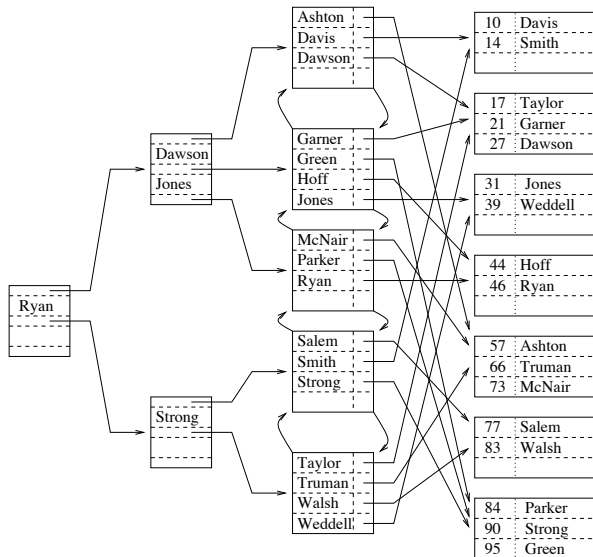
Clustering vs. Non-Clustering Indexes

- An index on attribute A of a relation is a **clustering** index if tuples in the relation with similar values for A are stored together in the same block.
- Other indices are **non-clustering** (or secondary) indices.

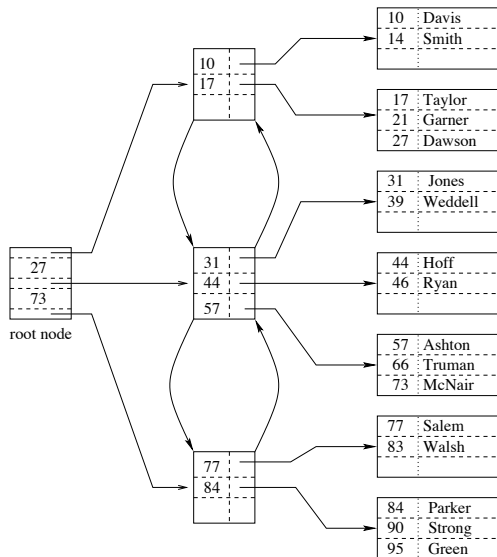
Note

A relation may have at most one clustering index, and any number of non-clustering indices.

Non-Clustering Index Example



Clustering Index Example



Definition (Co-Clustering)

Two relations are **co-clustered** if their tuples are interleaved within the same file

- Co-clustering is useful for storing hierarchical data (1:N relationships)
- Effects on performance:
 - Can speed up joins, particularly foreign-key joins
 - Sequential scans of either relation become slower

- B-trees can also help for range queries:

```
select *  
from R  
where A  $\geq$  c
```

- If a B-tree is defined on A , we can use it to find the tuples for which $A = c$. Using the forward pointers in the leaf blocks, we can then find tuples for which $A > c$.

Multi-Attribute Indices

- It is possible to create an index on several attributes of the same relation. For example:

```
create index NameIndex  
on Employee (Lastname,Firstname)
```

- The order in which the attributes appear is important. In this index, tuples (or tuple pointers) are organized first by Lastname. Tuples with a common surname are then organized by Firstname.

Using Multi-Attribute Indices

- The NameIndex index would be useful for these queries:

```
select *  
from Employee  
where Lastname = 'Smith'
```

```
select *  
from Employee  
where Lastname = 'Smith'  
and Firstname = 'John'
```

Using Multi-Attribute Indices

- The NameIndex index would be useful for these queries:

```
select *  
from Employee  
where Lastname = 'Smith'
```

```
select *  
from Employee  
where Lastname = 'Smith'  
and Firstname = 'John'
```

- It would be *very* useful for these queries:

```
select Firstname  
from Employee  
where Lastname = 'Smith'
```

```
select Firstname, Lastname  
from Employee
```

Using Multi-Attribute Indices

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```

- It would be *very* useful for these queries:

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select Firstname  
from Employee  
where Lastname = 'Smith'
```

```
select Firstname, Lastname  
from Employee
```

- It would not be useful at all for this query:

```
select *  
from Employee  
where Firstname = 'John'
```

Physical Design Guidelines

- 1 Don't index unless the performance increase outweighs the update overhead
- 2 Attributes mentioned in WHERE clauses are candidates for index search keys
- 3 Multi-attribute search keys should be considered when
 - a WHERE clause contains several conditions; or
 - it enables index-only plans
- 4 Choose indexes that benefit as many queries as possible
- 5 Each relation can have at most one clustering scheme; therefore choose it wisely
 - Target important queries that would benefit the most
 - Range queries benefit the most from clustering
 - Join queries benefit the most from co-clustering
 - A multi-attribute index that enables an index-only plan does not benefit from being clustered

DB2 Index Advisor

```
% db2advis -d sample -s "select empno,lastname
from employee where workdept = 'xxxx'"
Found maximum set of [1] recommended indexes
total disk space needed for initial set [ 0.005] MB
[ 50.5219] timerons (without indexes)
[ 25.1521] timerons (with current solution)
[%50.22] improvement
-- =====
-- index[1],      0.005MB
CREATE INDEX WIZ1517 ON "KMSALEM"."EMPLOYEE"
("WORKDEPT" ASC, "LASTNAME" ASC, "EMPNO" ASC) ;
-- =====
```

Tuning the Conceptual Schema

Suppose that after tuning the physical schema, the system still does not meet the performance goals!

- Adjustments can be made to the conceptual schema:
 - Re-normalization
 - Denormalization
 - Partitioning

Warning

Unlike changes to the physical schema, changes to the conceptual schema of an operational system—called *schema evolution*—often can't be completely masked from end users and their applications.

Denormalization

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In general, redundancy *increases update overhead* (due to change anomalies) but *decreases query overhead*.

The appropriate choice of normal form depends heavily upon the workload.

Partitioning

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 - ① **Horizontal Partitioning**
 - Each partition has all the original columns and a subset of the original rows
 - Tuples are assigned to a partition based upon a (usually natural) criteria
 - Often used to separate operational from archival data

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- *Partitioning* a table means splitting it into multiple tables for the purpose of reducing I/O cost or lock contention
 - 1 Horizontal Partitioning
 - Each partition has all the original columns and a subset of the original rows
 - Tuples are assigned to a partition based upon a (usually natural) criteria
 - Often used to separate operational from archival data
 - 2 Vertical Partitioning
 - Each partition has a subset of the original columns and all the original rows
 - Typically used to separate frequently-used columns from each other (concurrency *hot-spots*) or from infrequently-used columns

Tuning Queries

- Changes to the physical or conceptual schemas impacts *all* queries and updates in the workload.
- Sometimes desirable to target performance of specific queries or applications
- Guidelines for tuning queries:
 - 1 Sorting is expensive. Avoid unnecessary uses of ORDER BY, DISTINCT, or GROUP BY.
 - 2 Whenever possible, replace subqueries with joins
 - 3 Whenever possible, replace correlated subqueries with uncorrelated subqueries
 - 4 Use vendor-supplied tools to examine generated plan. Update and/or create statistics if poor plan is due to poor cost estimation.

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- 1 Minimize communication costs
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- 2 Minimize lock contention and hot-spots
 - Delay updates as long as possible
 - Delay operations on hot-spots as long as possible
 - Shorten or split transactions as much as possible
 - Perform insertions/updates/deletions in batches
 - Consider lower isolation levels