IT2201 / IT2601 / IT2564 / IT2621 / IT2521 / IT2323

Database Management Systems

Unit 7
Physical Database Design

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Topic Objectives

- At the end of this topic, you should be able to:
  - Describe the purpose and process of physical database design.
  - Apply the methodology in physical database design.

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Logical vs. Physical Database Design

- Logical Database Design (What)
  - The process of constructing a model of the information used in an enterprise;
  - It is independent of the functionality provided by the target DBMS, but dependent on the target data model (e.g. in our course, 'relational' data model is adopted).
- Physical Database Design (How)
  - The process of producing a description of the implementation of the database on secondary storage;
  - It requires the physical database designer to know the functionality of the target DBMS.

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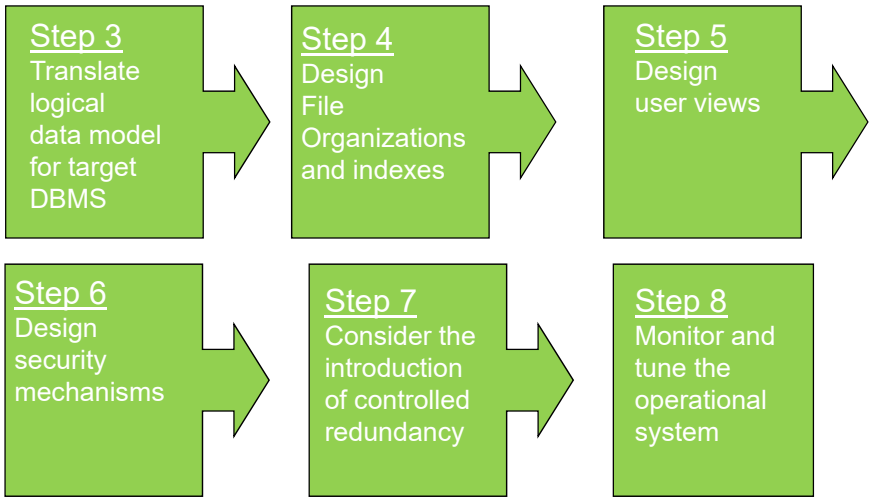
Overview of Physical Database Design



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Note: First 2 steps in logical database design

Step 3: Translate logical data model for target DBMS

- Objective
  - To produce a relational database schema that can be implemented in the target DBMS from the global logical data model.
  - Steps
    - 3.1 Design base relations
    - 3.2 Design representation of derived data
    - 3.3 Design general constraints

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Step 3.1: Design Base Relations

- Objective
  - To decide how to represent base relations identified in logical data model in the target DBMS.
- Tasks
  - Collate and assimilate information about the relations from the logical data model and data dictionary (produced during the logical database design) :
    - name of the relation
    - a list of simple attributes, any derived attributes
    - the primary key, alternate keys and foreign keys
    - referential integrity constraints
  - Decide how to implement the base relations using target DBMS
  - Document design of base relations.

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Documentation for the Base Relation

Consider the following relation in the logical data model:
Customer (custNum, cust_name, cust_addr)

The base relation is designed as follows:

Table Name: Customer
Table Description: This table stores customer details.

Column No.	Column Name	Column Description	Column Format	Key Type	Integrity Constraint
1.	custNum	Customer Number	N5	#	Not Null
2.	custName	Customer Name	C40		Not Null
3.	custAddr	Customer Address	C100		Not Null

Column Format:
c: character
n: number
d: date

Key Type:
#: primary key
f: foreign key
a: alternate key

Index: Nil

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Step 3.2: Design Representation of Derived Data

- Objective
  - To decide how to represent any derived data present in the logical data model in the target DBMS.
- Task
  - Examine logical data model and data dictionary, and produce list of all derived attributes.
  - Derived attribute can be stored in database or calculated every time it is needed.
    - Consider additional cost to store the derived data vs cost to calculate it each time it is required;
    - Less expensive option is chosen subject to performance constraints.
  - Document design of derived data.

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Customer Relation with Derived Attribute

Customer

Derive attribute

custNo	custName	custAddr	Acc_ balance
27889	John Little	33 High St	12,000
12008	Robinson	2 Queen St	28,000
23665	Johnson	11 Steven Rd	21,000

Acc_bal = ∑total order amt - ∑total payment amt

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Step 3.3: Design general constraints

- Objective
  - To design the general constraints for the target DBMS.
- Task
  - Consider the remaining general constraints. Eg prevent a customer from owing debt > 100,000. We can define this constraint into the SQL Create Table as follows:

    CONSTRAINT debt_limit
    CHECK (value <= 100,000)
  - Document design of general constraints.

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Step 4: Design File organizations and indexes

- Objective
  - To determine the optimal file organizations to store the base relations and the indexes that are required to achieve **acceptable performance**.
  - Steps
    - 4.1 Analyze transactions
    - 4.2 Choose file organizations
    - 4.3 Choose indexes
    - 4.4 Estimate disk space requirements

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Indexes

- What is an Index ?
  - Indexes are data structures which points to the data rows.
  - It is used for locating and retrieving of data more quickly.
  - It helps to avoid the need to scan the table sequentially for a particular record.
  - Similar to an index at the end of a textbook.

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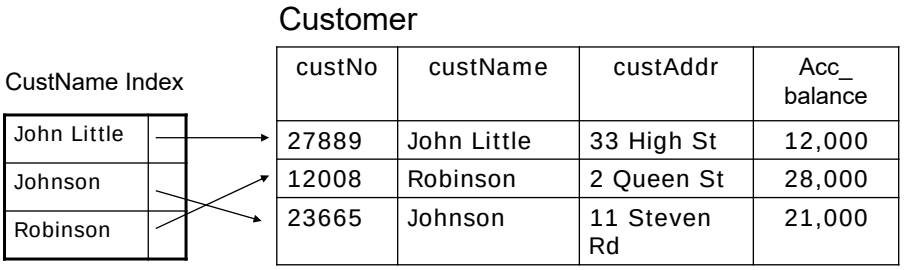
Indexes

- An index contains records consisting of the key value and the address of the records in the data file.
- The below figure illustrates an index created on the customer name column.



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Types of Index

- There are different types of index, the main ones being:
  - Primary index
    - The data file is sequentially ordered by an ordering key field, and the index is built on the ordering key field, which is guarantee to have a unique value in each record.
  - Clustering index
    - The data is sequentially ordered on a non-key field, and the indexing is built on this non-key field, so that there can be more than one record corresponding to a value of the indexing field.
  - Secondary index
    - An index that is defined on a non-ordering field of the data file.

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Types of Indexes

Remember that Indexes are built on columns:

Type of Index	Is this column a key ?	Data sorted on this column ?
Primary Index	Yes	Yes
Clustering Index	No	Yes
Secondary Index	No	No

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Review question 1

- In the following Student relation, the primary key is adminNo and the data file is ordered in adminNo sequence.
  - Student (AdminNo, Name, NRIC, address)
- We created two indexes on this relation: one is adminNo and the other is NRIC. Identify type of these two indexes.
  - Ans:
- If we order the file in Name sequence and create an index on Name. what is this type of index?
  - Ans:

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Choose Indexes

- Objective
  - To determine whether adding indexes will improve the performance of the system.
- Purpose
  - Secondary indexes provide a mechanism for specifying an additional key for a base relation that can be used to retrieve data more efficiently.
- Considerations
  - Overhead involved in the maintenance and use of secondary indexes vs performance improvement gained

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Specifying Indexes

- Task
  - Create index using the SQL statement
  - For example, to create a primary index on the Customer relation based on the custNo attribute:
    - CREATE UNIQUE INDEX custNoInx ON Customer (custNo);
  - Create a secondary index on the Customer relation based on the custName attribute:
    - CREATE INDEX custNameInx ON Customer(custName);
  - Document choice of secondary indexes.

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Guidelines for choosing secondary indexes

- When to create an Index ?
  - Index the primary key of a relation if it is not a key of the file organization.
  - Add secondary index to a foreign key if it is frequently accessed.
  - Add secondary index on columns that are involved in:
    - selection or join criteria
    - ORDER BY
    - GROUP BY
- When not to create an index ?
  - Do not index small tables.
  - Avoid indexing a column or table that is frequently updated.
  - Avoid indexing a column if the query will retrieve a significant proportion (e.g. 25%) of the rows in the table.
  - Avoid indexing columns that consist of long character strings.

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Step 5: Design User Views

- Objective
  - To design the user views that were identified during the Requirements Collection and Analysis stage of the relational database application lifecycle.
- Advantages of user views :
  - Data independence
  - Reduced complexity
- Task
  - Create views using CREATE VIEW SQL statement.
  - Document design of user views.
- For example, to restrict users to access to a subset of staff particulars, a view allStaff is created as follows:

```
CREATE VIEW allStaff
AS SELECT  staffNo, fname, lname, branchNo
        FROM  staff;
```

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Step 6: Design Security Measures

- Objective
  - To design the security measures for the database as specified by the users.
- 2 types of database security :
  - **System security** – covers access at system level, such as a user name and password.
  - **Data security** – covers access of database objects, such as relations and views, and the actions that users can have on the objects.
- Task
  - Design access rules using GRANT, REVOKE SQL statement
  - Document design of security measures.
- Example: Give users Personnel and Director the privileges SELECT and UPDATE on column salary of the Staff table.

```
GRANT SELECT, UPDATE (salary)
ON staff
TO Personnel, Director;
```

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Step 7: Consider the Introduction of Controlled Redundancy

- Objective
  - To determine whether introducing redundancy in a controlled manner by relaxing the normalization rules will improve the performance of the system.
- The results of normalization is a logical database design that is structurally consistent and has minimal redundancy.
- A normalized database design does not provide maximum processing efficiency.
- In favor of performance, denormalization may be necessary.

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Denormalization

- Denormalization refers to
  - Refinement to the relational schema (i.e. lessen the degree of normalization);
  - Combine two relations into one new relation;
  - Also called usage refinement.
- Factors to be considered
  - Denormalization makes implementation more complex.
  - Denormalization often sacrifices flexibility.
  - Denormalization may speed up retrievals but it slows down updates.

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Denormalization

- When to Denormalize
  - Performance is unsatisfactory.
  - Relations have low update rate and a very high query rate.
- Where to Denormalize
  - Consider derived data.
  - Consider duplicating attributes or joining relations together (to reduce the no. of joins).

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Denormalization

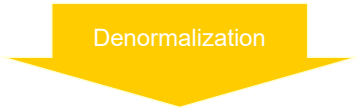
- Duplicating Attributes or Joining Relations
  - An Example

Branch (3NF)

BNO	Street	PCode	Phone	Fax

PostCode (3NF)

PCode	Area	City



Branch (2NF)

BNO	Street	Area	City	PCode	Phone	Fax

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Denormalization

- Consider Denormalization in the following situations.
  - Combining one-to-one (1:1) relationships.
  - Duplicating nonkey attributes in one-to-many (1:M) relationships to reduce joins.
  - Duplicating foreign key attributes in one-to-many (1:M) relationships to reduce joins.
  - Duplicating attributes in many-to-many(M:M) relationships to reduce joins.
  - Introducing repeating groups.
  - Merging lookup tables with base relations.
  - Creating extract tables.

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Step 7: Consider the Introduction of Controlled Redundancy (cont'd)

- Document introduction of redundancy
  - The introduction of redundancy should be fully documented, along with the reasons for introducing it.
  - Document the reasons for selecting one approach where many alternatives exist.
  - Update the logical data model to reflect any changes made as a result of denormalization.

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Step 8: Monitor and Tune the Operational System

- Objective
  - To monitor the operational system and improve the performance of the system to correct inappropriate design decisions or reflect changing requirements.
- Many DBMSs provide the DBA with utilities to monitor the operation of the system and tune it.

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Quiz

Across

1. The process of transforming normalized relations into unnormalized physical record specifications.
3. Denormalize relations that have low update rate and high ____ rate.
5. Avoid indexing an attribute that is frequently _____.
7. _____ security covers access of database objects such as relations and views.
9. Avoid indexing columns that consists of _____ character strings.

Down

2. A table or other data structure used to determine the location of rows in a file that satisfies some condition.
4. An index that is defined on a non-ordering field of the data file.
6. An attribute that can be computed based on existing data is called _____ attribute.
8. The tuples of _____ relation are physically stored in the database.
10. _____Database Design is based on a specific data model, but independent of a particular DBMS.

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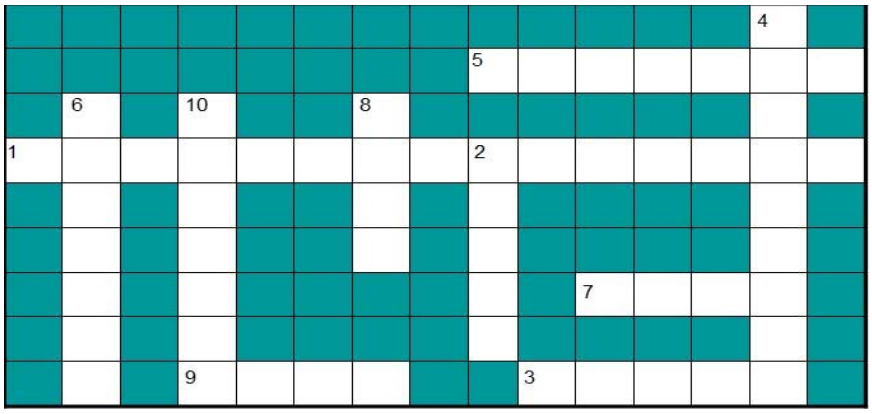
Quiz



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Summary

- Physical database design is the process of producing a description of the implementation of the database on secondary storage.
- It describes the base tables and indexes used to access this data effectively, and any associated integrity constraints and security restrictions.

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Reference Materials

1. Database Systems, Connolly, Ch 18
2. Database Solutions, Connolly, Ch 12-16

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