Database Systems: A Practical Approach to Design, Implementation, and Management

Sixth Edition

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Chapter 7

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: Data Definition

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Learning Objectives (1 of 2)

7.1 Data types supported by SQL standard.

7.2 Purpose of integrity enhancement feature of SQL.

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7.3 How to define ing SQL.

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7.4 How to use th t feature in the CREATE and ALTER TABLE st

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Learning Objectives (2 of 2)

7.5 Purpose of views.

7.6 How to create and delete views using SQL.

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7.7 How the DBM on views.

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7.8 Under what c atable.

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7.9 Advantages and disadvanta s.

7.10 How the ISO transaction model works.

7.11 How to use the GRANT and REVOKE statements as a level of security.

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Table 7.1 ISO SQL Data Types

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†BIT and BIT VARYING have been removed from the SQL:2003 standard.

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Integrity Enhancement Feature (1 of 4)

- Consider five types of integrity constraints:
  - required data
  - domain constraints
  - entity integri
  - referential i
  - general constraints.

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Integrity Enhancement Feature (2 of 4)

Required Data

position VARCHAR(10) NOT NULL

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Domain Constra

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(a) **CHECK**

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```
sex CHAR NOT NULL
            CHECK (sex IN ('M', 'F'))
```

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Integrity Enhancement Feature (3 of 4)

(b) **CREATE DOMAIN**

CREATE DOMAIN DomainName [AS] dataType

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[DEFAUL

[CHECK (

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For example:

```
CREATE DOMAIN SexType AS CHAR
        CHECK (VALUE IN ('M', 'F'));
sex SexType NOT NULL
```

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Integrity Enhancement Feature (4 of 4)

- **searchCondition** can involve a table lookup:

CREATE DOMAIN BranchNo AS CHAR(4)
CHECK (V chNo
));

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- Domains can be removed usin OMAIN:

DROP DOMAIN DomainName
[RESTRICT | CASCADE]

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IEF - Entity Integrity

- Primary key of a table must contain a unique, non-null value for each row.

- ISO standard supports FOREIGN KEY clause in CREATE and ALTER TA

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  PRIMARY KEY(staffNo)

  PRIMARY KEY(clientNo, p

- Can only have one PRIMARY KEY clause per table. Can still ensure uniqueness for alternate keys using UNIQUE:

  UNIQUE(telNo)

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IEF - Referential Integrity (1 of 4)

- FK is column or set of columns that links each row in child table containing foreign FK to row of parent table containing matching PK.

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- Referential inte ontains a value, that value must arent table.

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- ISO standard supports definiti ith FOREIGN KEY clause in CREATE and ALTER TABLE:

FOREIGN KEY(branchNo) REFERENCES Branch

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IEF - Referential Integrity (2 of 4)

- Any INSERT/UPDATE attempting to create FK value in child table without matching CK value in parent is rejected.

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- Action taken att https://eduassistpro.github.io/ e a CK value in parent table wit is dependent on **referential action** Add WeChat edu_assist_pro DATE and ON DELETE subclauses:
  - CASCADE - SET NULL
  - SET DEFAULT - NO ACTION

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IEF - Referential Integrity (3 of 4)

CASCADE: Delete row from parent and delete matching rows in child, and so on in cascading manner.

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SET NULL: Delete row from parent and set FK column(s) in child to NULL. are NOT NULL.

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SET DEFAULT: Delete row fro d set each component of FK in child to spe lt. Only valid if DEFAULT specified for FK columns.

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NO ACTION: Reject delete from parent. Default.

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IEF - Referential Integrity (4 of 4)

FOREIGN KEY (staffNo) REFERENCES Staff

ON DELETE SET NULL

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FOREIGN KEY (S Owner

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ON UPDATE

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IEF - General Constraints (1 of 2)

- Could use CHECK/UNIQUE in CREATE and ALTER TABLE.
- Similar to the CHECK clause, also have:

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CREATE ASS[illegible]e

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CHECK (searchCondition)

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IEF - General Constraints (2 of 2)

CREATE ASSERTION StaffNotHandlingTooMuch

CHECK (NOT EXISTS (SELECT staffNo

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FROM PropertyForRent

No

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(*) > 1))

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Data Definition (1 of 2)

- SQL DDL allows database objects such as schemas, domains, tables, views, and indexes to be created and destroyed.

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- Main SQL DDL

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CREATE SCHEMA	DROP S
CREATE/ALTER DOMAIN	DROP D
CREATE/ALTER TABLE	DROP TABLE
CREATE VIEW	DROP VIEW

- Many DBMSs also provide:

CREATE INDEX	DROP INDEX

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Data Definition (2 of 2)

- Relations and other database objects exist in an **environment**.

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- Each environment contains one or more **catalogs**, and each catalog co s.

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- Schema is named collection o tabase objects.

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- Objects in a schema can be t , domains, assertions, collations, translations, and character sets. All have same owner.

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CREATE SCHEMA

CREATE SCHEMA [Name |
AUTHORIZATION CreatorId]

DROP SCHEMA Name [RESTRICT | CASCADE]

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- With RESTRIC[illegible]t be empty or operation fails.
- With CASCADE, operation cascades to drop all objects associated with schema in order defined above. If any of these operations fail, DROP SCHEMA fails.

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CREATE TABLE (1 of 2)

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CREATE TABLE (2 of 2)

- Creates a table with one or more columns of the specified **dataType**.
- With NOT NULL, system rejects any attempt to insert a null in the colu
- Can specify a DEFAULT valu umn.
- Primary keys should always b as NOT NULL.
- FOREIGN KEY clause specifies FK along with the referential action.

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Example 7.1 - CREATE TABLE (1 of 2)

```
CREATE DOMAIN OwnerNumber AS VARCHAR(5)
   CHECK (VALUE IN (SELECT ownerNo FROM PrivateOwner));
CREATE DOMAIN StaffNumber AS VARCHAR(5)
   CHECK (VALUE                                    M Staff));
CREATE DOMAIN                                    (5);
CREATE DOMAIN PRooms AS S
         CHECK(VALUE BETWEEN 1 AND 15);
CREATE DOMAIN PRent AS DECIMAL(6,2)
         CHECK(VALUE BETWEEN 0 AND 9999.99);
```

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Example 7.1 - CREATE TABLE (2 of 2)

CREATE TABLE PropertyForRent (

propertyNo Pnumber NOT NULL, ….

rooms PRooms NOT NULL DEFAULT 4,

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rent PRent NO

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ownerNo Owne

staffNo StaffNumber

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Constraint StaffNotHandlingTooMuch ….

branchNo BranchNumber NOT NULL,

PRIMARY KEY (propertyNo),

FOREIGN KEY (staffNo) REFERENCES Staff

ON DELETE SET NULL ON UPDATE CASCADE ….);

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ALTER TABLE

- Add a new column to a table.
- Drop a column from a table.
- Add a new tabl
- Drop a table co
- Set a default for a column.
- Drop a default for a column.

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Example 7.2(a) – ALTER TABLE

Change Staff table by removing default of 'Assistant' for position column and setting default for sex column to female ('F').

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```
ALTER TAB
ALTER position DROP DE
ALTER TABLE Staff
ALTER sex SET DEFAULT 'F';
```

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Example 7.2(b) – ALTER TABLE

Remove constraint from PropertyForRent that staff are not allowed to handle more than 100 properties at a time. Add new column to Client table.

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```
ALTER TABLE P

    DROP CONSTRAINT Staff          gTooMuch;

ALTER TABLE Client

    ADD prefNoRooms PRooms;
```

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DROP TABLE

DROP TABLE TableName [RESTRICT | CASCADE]

e.g. DROP TABLE PropertyForRent;

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- Removes name https://eduassistpro.github.io/ hin it.
- With RESTRICT, if any other Add WeChat edu_assist_pro end for their existence on continued existe able, SQL does not allow request.
- With CASCADE, SQL drops all dependent objects (and objects dependent on these objects).

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Views (1 of 2)

View

Dynamic result of one or more relational operations operating on base relations to produce another relation.

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- Virtual relation t y actually exist in the database but is produced st, at time of request.

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Views (2 of 2)

- Contents of a view are defined as a query on one or more base relations.

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- With **view resolution**, any operations on view are automatically tr on relations from which it is deriv

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- With **view materialization**, th ored as a temporary table, which is maintained as the underlying base tables are updated.

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SQL - CREATE VIEW (1 of 2)

CREATE VIEW ViewName [(newColumnName [,...])]
AS subselect
[WITH [CASCADED | LOCAL] CHECK OPTION]

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- Can assign a n https://eduassistpro.github.io/ view.
- If list of column names is spec Add WeChat edu_assist_pro t have same number of items as number of columns produced by **subselect**.
- If omitted, each column takes name of corresponding column in **subselect**.

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SQL - CREATE VIEW (2 of 2)

- List must be specified if there is any ambiguity in a column name.
- The **subselect** is known as the **defining query**.
- WITH CHECK a row fails to satisfy WHERE clause of defi it is not added to underlying base table.
- Need SELECT privilege on all tables referenced in subselect and USAGE privilege on any domains used in referenced columns.

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Example 7.3 - Create Horizontal View

Create view so that manager at branch B003 can only see details for staff who work in his or her office.

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```
CREATE VIEW Manager3Staff
AS SELECT *
    FROM Staff
    WHERE branchNo = 'B003';
```

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staffNo	fName	lName	position	sex	DOB	salary	branchNo
SG37	Ann	Beech	Assistant	F	10-Nov-60	12000.00	B003
SG14	David	Ford	Supervisor	M	24-Mar-58	18000.00	B003
SG5	Susan	Brand	Manager	F	3-Jun-40	24000.00	B003

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Example 7.4 - Create Vertical View

Create view of staff details at branch B003 excluding salaries.

```
CREATE VIEW Staff3
AS SELECT staff                          ition, sex
    FROM Staff
    WHERE branchNo = 'B003';
```

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staffNo	fName	lName	position	sex
SG37	Ann	Beech	Assistant	F
SG14	David	Ford	Supervisor	M
SG5	Susan	Brand	Manager	F

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Example 7.5 - Grouped and Joined Views

Create view of staff who manage properties for rent, including branch number they work at, staff number, and number of properties they manage.

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```
CREATE VIEW S                     staffNo, cnt)
 AS SELECT s.branchNo, s.staf                T(*)
      FROM Staff s, PropertyFor
      WHERE s.staffNo = p.staffNo
      GROUP BY s.branchNo, s.staffNo;
```

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Example 7.3 - Grouped and Joined Views

branchNo	staffNo	cnt
B003	SG14	1
B0		
B0		
B007	SA9	

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SQL - DROP VIEW (1 of 2)

DROP VIEW ViewName [RESTRICT | CASCADE]

- Causes definition of view to be deleted from database.
- For example:

DROP VIEW Manager3Staff;

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SQL - DROP VIEW (2 of 2)

- With CASCADE, all related dependent objects are deleted; i.e. any views defined on view being dropped.
- With RESTRICT (default), if any other objects depend for their existence of view being dropped, comm

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View Resolution (1 of 4)

Count number of properties managed by each member at branch B003.

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```
SELECT sta
FROM Staff
WHERE branchNo = ‘B003
ORDER BY staffNo;
```

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View Resolution (2 of 4)

(a) View column names in SELECT list are translated into their corresponding column names in the defining query:

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SELECT s.st T(*) As cnt

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(b) View names in FROM are re corresponding FROM lists of defining query

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FROM Staff s, PropertyForRent p

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View Resolution (3 of 4)

(c) WHERE from user query is combined with WHERE of defining query using AND:

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WHERE s.staffNo = p.staffNo AND branchNo = ‘B003’

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(d) GROUP BY a [illegible] ied from defining query:

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GROUP BY s.branchNo, s.staffNo

(e) ORDER BY copied from query with view column name translated into defining query column name

ORDER BY s.staffNo

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View Resolution (4 of 4)

(f) Final merged query is now executed to produce the result:

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```
SELECT s.staffNo AS staffNo, COUNT(*) AS cnt
FROM Staff
WHERE s.staffNo = p.staff
              branchNo = ‘B00
GROUP BY s.branchNo, s.staffNo
ORDER BY s.staffNo;
```

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Restrictions on Views (1 of 3)

SQL imposes several restrictions on creation and use of views.

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(a) If column in view is based on an aggregate function:

- Column ma https://eduassistpro.github.io/ T and ORDER BY clauses of queries that ac
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- Column may not be us ERE nor be an argument to an aggregate function in any query based on view.

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Restrictions on Views (2 of 3)

- For example, following query would fail:

```
SELECT COUNT(cnt)
FROM
```

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- Similarly, following query woul

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```
SELECT *
FROM StaffPropCnt
WHERE cnt > 2;
```


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Restrictions on Views (3 of 3)

(b) Grouped view may never be joined with a base table or a view.

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- For example, St uped view, so any attempt to j r table or view fails.

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View Updatability (1 of 5)

- All updates to base table reflected in all views that encompass base table.
- Similarly, may expect that if view is updated then base table(s) will refl

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View Updatability (2 of 5)

- However, consider again view StaffPropCnt.
- If we tried to insert record showing that at branch B003, SG5 manages 2 properties:

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```
INSERT IN
VALUES (‘B003’, ‘SG5’, 2
```

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- Have to insert 2 records into PropertyForRent showing which properties SG5 manages. However, do not know which properties they are; i.e. do not know primary keys!

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View Updatability (3 of 5)

- If change definition of view and replace count with actual property numbers:

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CREATE VIE No,

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AS SELECT s.branchNo, s. ropertyNo

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FROM Staff s, Property

WHERE s.staffNo = p.staffNo;

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View Updatability (4 of 5)

- Now try to insert the record:

```
INSERT INTO StaffPropList
VALUES ('
```

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- Still problem, because in Prop t all columns except postcode/staffNo are n nulls.
- However, have no way of giving remaining non-null columns values.

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View Updatability (5 of 5)

- ISO specifies that a view is updatable if and only if:
  - DISTINCT is not specified.
  - Every element in SELECT list of defining query is a column name and no an once.
  - FROM claus excluding any views based on a join, union, or difference.
  - No nested SELECT referenc le.
  - No GROUP BY or HAVING clause.
  - Also, every row added through view must not violate integrity constraints of base table.

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Updatable View

For view to be updatable, DBMS must be able to trace any row or column back to its row or column in the source table.

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WITH CHECK OPTION (1 of 2)

- Rows exist in a view because they satisfy WHERE condition of defining query.
- If a row changes and no longer satisfies condition, it disappears fro
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- New rows appear within view t/update on view cause them to satisfy WHERE
- Rows that enter or leave a view are called **migrating rows**.
- WITH CHECK OPTION prohibits a row migrating out of the view.

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WITH CHECK OPTION (2 of 2)

- LOCAL/CASCADED apply to view hierarchies.
- With LOCAL, any row insert/update on view and any view directly or indirectly defined on this view must not cause row to disappe also disappears from derived vi

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- With CASCADED (default), a rt/ update on this view and on any view directly or indirectly defined on this view must not cause row to disappear from the view.

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Example 7.6 - WITH CHECK OPTION (1 of 4)

```
CREATE VIEW Manager3Staff
AS SELECT *
    FROM Staff
    WHERE
WITH CHE
```

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- Cannot update branch numbe 03 to B002 as this would cause row to migrate from view.
- Also cannot insert a row into view with a branch number that does not equal B003.

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Example 7.6 - WITH CHECK OPTION (2 of 4)

- Now consider the following:

```
CREATE VIEW LowSalary
 AS SELECT *                                    lary > 9000;
CREATE VIEW
 AS SELECT * FROM LowSal
              WHERE salary > 10000
 WITH LOCAL CHECK OPTION;
CREATE VIEW Manager3Staff
 AS SELECT * FROM HighSalary
              WHERE branchNo = 'B003';
```

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Example 7.6 - WITH CHECK OPTION (3 of 4)

```
UPDATE Manager3Staff
SET salary = 9500
WHERE staffNo = 'SG37';
```

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- This update wo ... would cause row to disappear from HighSalary, ... not disappear from LowSalary.

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- However, if update tried to set salary to 8000, update would succeed as row would no longer be part of LowSalary.

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Example 7.6 - WITH CHECK OPTION (4 of 4)

- If HighSalary had specified WITH CASCADED CHECK OPTION, setting salary to 9500 or 8000 would be rejected because row would disappear from HighSalary.

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- To prevent ano ew should be created using CK OPTION.

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Advantages of Views

- Data independence
- Currency
- Improved secur
- Reduced compl
- Convenience
- Customization
- Data integrity

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Disadvantages of Views

- Update restriction
- Structure restriction
- Performance

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View Materialization (1 of 2)

- View resolution mechanism may be slow, particularly if view is accessed frequently.
- View materialization stores view as temporary table when view is first que
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- Thereafter, queries based on d view can be faster than recomputing view
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- Difficulty is maintaining the currency of view while base tables(s) are being updated.

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View Maintenance

- **View maintenance** aims to apply only those changes necessary to keep view current.
- Consider following view:

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```
CREATE VI                                   No)
AS SELECT DISTINCT st
          FROM Propert
          WHERE branchNo = 'B003' AND
                rent > 400;
```

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staffNo
SG37
SG14

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View Materialization (2 of 2)

- If insert row into PropertyForRent with rent ≤400 then view would be unchanged.
- If insert row for property PG24 at branch B003 with staffNo = SG19 and rent = 550, th [illegible] rialized view.
- If insert row for pro [illegible] with staffNo = SG37 and rent = 450, then no new row wo [illegible] e added to materialized view.
- If delete property PG24, row should be deleted from materialized view.
- If delete property PG54, then row for PG37 should not be deleted (because of existing property PG21).

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Transactions (1 of 3)

- SQL defines transaction model based on COMMIT and ROLL BACK.
- Transaction is logical unit of work with one or more SQL statements guar espect to recovery.
- An SQL transact ith a **transaction-initiating** SQL statement (e.g., S ERT).
- Changes made by transaction are not visible to other concurrently executing transactions until transaction completes.

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Transactions (2 of 3)

- Transaction can complete in one of four ways:
  - COMMIT ends transaction successfully, making changes permanent.
  - ROLLBACK king out any changes m
  - For programmatic SQL, su ogram termination ends final transaction successfully, even if COMMIT has not been executed.
  - For programmatic SQL, abnormal program end aborts transaction.

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Transactions (3 of 3)

- New transaction starts with next transaction-initiating statement.
- SQL transactions cannot be nested.
- SET TRANSAC[illegible]ction:

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SET TRANSACTION
    [READ ONLY | READ WRITE] |
    [ISOLATION LEVEL READ UNCOMMITTED |
    READ COMMITTED | REPEATABLE READ |
    SERIALIZABLE]

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Immediate and Deferred Integrity Constraints (1 of 2)

- Do not always want constraints to be checked immediately, but instead at transaction commit.
- Constraint may be defined as INITIALLY IMMEDIATE or INITIALLY DEF e the constraint assumes at sta

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- In former case, also possible t hether mode can be changed subsequently using qualifier [NOT] DEFERRABLE.
- Default mode is INITIALLY IMMEDIATE.

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Immediate and Deferred Integrity Constraints (2 of 2)

- SET CONSTRAINTS statement used to set mode for specified constraints for current transaction:

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Access Control - Authorization Identifiers and Ownership

- Authorization identifier is normal SQL identifier used to establish identity of a user. Usually has an associated password.

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- Used to determ ay reference and what operation those objects.

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- Each object created in SQL h r, as defined in **Authorization** clause of schema to which object belongs.
- Owner is only person who may know about it.

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Privileges (1 of 2)

- Actions user permitted to carry out on given base table or view:

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SELECT Retrieve data from a table.

INSERT Insert ne

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UPDATE Modify rows of data in

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DELETE Delete rows of data fro

REFERENCES Reference columns of named table in integrity constraints.

USAGE Use domains, collations, character sets, and translations.

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Privileges (2 of 2)

- Can restrict INSERT/UPDATE/REFERENCES to named columns.
- Owner of table must grant other users the necessary privileges using
- To create view, user must ha privilege on all tables that make up view and CES privilege on the named columns.

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GRANT (1 of 2)

GRANT {PrivilegeList | ALL PRIVILEGES}

ON ObjectName

TO{AuthorizationIdList | PUBLIC}

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[WITH GRAN

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- **PrivilegeList** consists of one above privileges separated by commas.
- **ALL PRIVILEGES** grants all privileges to a user.

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GRANT (2 of 2)

- PUBLIC allows access to be granted to all present and future authorized users.
- **ObjectName** can be a base table, view, domain, character set, c
- WITH GRANT OPTION allow to be passed on.

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Example 7.7-7.8 - GRANT

Give Manager full privileges to Staff table.

```
GRANT ALL PRIVILEGES
ON Staff
TO Manag[illegible]N;
```

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Give users Personnel and Direc[illegible]T and UPDATE on column salary of Staff.

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

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Example 7.9 - GRANT Specific Privileges to PUBLIC

Give all users SELECT on Branch table.

```
GRANT SELECT
ON Branch
TO PUBLI
```

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REVOKE (1 of 3)

- REVOKE takes away privileges granted with GRANT.

```
REVOKE [GRANT OPTION FOR]
        {Privil                                  ES}
ON Object
FROM {AuthorizationIdLi          }
            [RESTRICT | CASCADE]
```

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- ALL PRIVILEGES refers to all privileges granted to a user by user revoking privileges.

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REVOKE (2 of 3)

- GRANT OPTION FOR allows privileges passed on via WITH GRANT OPTION of GRANT to be revoked separately from the privileges themselves.

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- REVOKE fails i ed object, such as a view, unle rd has been specified.

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- Privileges granted to this user by other users are not affected.

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REVOKE (3 of 3)

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Example 7.10 -7.11 - REVOKE Specific Privileges

Revoke privilege SELECT on Branch table from all users.

REVOKE SELECT
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ON Branch
FROM PUB
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Revoke all privileges given to Di taff table.

REVOKE ALL PRIVILEGES
ON Staff
FROM Director;

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Chapter 8

Advanced SQL

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Learning Objectives

8.1 How to use the SQL programming language

8.2 How to use SQL cursors

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8.3 How to create

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8.4 How to create

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8.5 How to use triggers to enfor constraints

8.6 The advantages and disadvantages of triggers

8.7 How to use recursive queries

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The SQL Programming Language (1 of 2)

- Impedance mismatch
  - Mixing different programming paradigms
  - SQL is a declarative language
  - High-level l procedural language
  - SQL and 3GLs use differe o represent data

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The SQL Programming Language (2 of 2)

- SQL/PSM (Persistent Stored Modules)
- PL/SQL (Procedural Language/SQL)
  - Oracle's procedural extension to SQL
  - Two version

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Declarations (1 of 2)

- Variables and constant variables must be declared before they can be referenced
- Possible to declare a variable as NOT NULL
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- %TYPE – varia mn
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  - vStaffNo Staff.staffNo%TY
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- %ROWTYPE – variable same type as an entire row
  - vStaffNo1 Staff%ROWTYPE;

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Declarations (2 of 2)

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Assignments

- Variables can be assigned in two ways:
  - Using the normal assignment statement (:=):

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vStaffNo :

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- Using an SQL ment:

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SELECT COUNT(*) **INTO** x

FROM PropertyForRent

WHERE staffNo = vStaffNo;

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Control Statements

- Conditional IF statement
- Conditional CASE statement
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- Iteration statem
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- Iteration statem T)
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- Iteration statement (FOR)

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Conditional IF Statement

```
IF (position = 'Manager') THEN
    salary := salary*1.05;
ELSE
    salary := sala
END IF;
```

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Conditional CASE Statement

```
UPDATE Staff
SET salary = CASE
        WHEN position = 'Manager'
        THEN sal
        ELSE
        salary * 1.02
END;
```

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Iteration Statement (LOOP)

```
x:=1;
myLoop:
LOOP
        x := x+1;
        IF (x > 3)
                EXIT myLoop; --- e
END LOOP myLoop;
--- control resumes here
y := 2;
```

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Iteration Statement (WHILE and REPEAT)

WHILE (condition) **DO**

<SQL statement list>

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END WHILE [lab

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REPEAT

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<SQL statement list>

UNTIL (condition)

END REPEAT [labelName];

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Iteration Statement (FOR)

myLoop1:

FOR iStaff **AS SELECT COUNT**(*) **FROM**

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PropertyForRent 4’ **DO**

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.....

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END FOR myLoop1;

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Exceptions in PL/SQL

- Exception
  - Identifier in PL/SQL
  - Raised during the execution of a block
  - Terminates tions
- Exception handlers
  - Separate routines that han exceptions
- User-defined exception
  - Defined in the declarative part of a PL/SQL block

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Example of Exception Handling in PL/SQL

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Condition Handling

- Define a handler by:
  - Specifying its type
  - Exception and completion conditions it can resolve
  - Action it tak
- Handler is activated:
  - When it is the most appro er for the condition that has been raised by the SQL statement

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The DECLARE . . . HANDLER Statement

DECLARE {**CONTINUE | EXIT | UNDO**} **HANDLER**

FOR SQLSTATE {sqlstateValue | conditionName **| SQL EXCEPTION | SQLWARNING | NOT FOUND**} handler Action;

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Cursors in PL/SQL

- **Cursor**
  - Allows the rows of a query result to be accessed one at a time
  - Must be de e use
  - Must be clo it is no longer required
  - Updating rows through a cursor

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Using Cursors in PL/SQL to Process a Multirow Query

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Subprograms, Stored Procedures, Functions, and Packages (1 of 2)

- **Subprograms**
  - Named PL/SQL blocks that can take parameters and be invoked
- Two types:
  - Stored procedures
  - Functions (returns a single ller)
- Can take a set of parameters
  - Each has name and data type
  - Can be designated as IN, OUT, IN OUT

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Subprograms, Stored Procedures, Functions, and Packages (2 of 2)

- **Package**
  - Collection of procedures, functions, variables, and SQL statements that are grouped together and stored as a
- Specification
  - Declares all public constru ackage
- Body
  - Defines all constructs (public and private) of the package

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Triggers

- **Trigger**
  - Defines an action that the database should take when some event occurs in the application.
  - Based on Ev) model

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- Types
  - Row-level
  - Statement-level
- Event: INSERT, UPDATE or DELETE
- Timing: BEFORE, AFTER or INSTEAD OF
- Advantages and disadvantages of triggers

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Trigger Format

CREATE TRIGGER TriggerName

BEFORE | **AFTER** | **INSTEAD OF**

INSERT | **DELETE** | **UPDATE** [**OF** TriggerColumnList]

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ON TableNam

[**REFERENCI**

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Name | NewName}

[**FOR EACH** {**ROW** | **STATEM**

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[**WHEN** Condition]

<trigger action>

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Using a BEFORE Trigger

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Triggers – Advantages

- Elimination of redundant code
- Simplifying modifications
- Increased secu
- Improved integr
- Improved processing power
- Good fit with client-server architecture

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Triggers – Disadvantages

- Performance overhead
- Cascading effects
- Cannot be sche
- Less portable

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Recursion

- Extremely difficult to handle recursive queries
  - Queries about relationships that a relation has with itself (directly or indirectly)
- WITH RECUR this
- Infinite loop can occur unless n be detected
  - CYCLE clause

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Recursion - Example

```
WITH RECURSIVE
AllManagers (staffNo, managerStaffNo) AS
(SELECT staffNo, managerStaffNo
FROM Staff
UNION
SELECT in.staffNo, out.managerS
FROM AllManagers in, Staff out
WHERE in.managerStaffNo = out.staffNo);
SELECT * FROM AllManagers
ORDER BY staffNo, managerStaffNo;
```

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Chapter 10

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abase System
ment Lifecycle

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Learning Objectives

10.1 Main components of an information system.

10.2 Main stages of database system development lifecycle.

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10.3 Main phases of database design: conceptual, logical, and physical design.

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10.4 Benefits of CASE tools.

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10.5 How to evaluate and select a DBMS.

10.6 Distinction between data administration and database administration.

10.7 Purpose and tasks associated with data administration and database administration.

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Software Depression (1 of 3)

- Last few decades have seen proliferation of software applications, many requiring constant maintenance involving:
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  - correcting f
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  - implementin ts,
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  - modifying software to run pgraded platforms.
- Effort spent on maintenance began to absorb resources at an alarming rate.

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Software Depression (2 of 3)

- As a result, many major software projects were
  - late,
  - over budget,
  - unreliable,
  - difficult to m
  - performed poorly.
- In late 1960s, led to ‘software crisis’, now refer to as the ‘software depression’.

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Software Depression (3 of 3)

- Major reasons for failure of software projects includes:
  - lack of a complete requirements specification;
  - lack of appropriate development methodology;
  - poor decom anageable component

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- Structured approach to develo proposed called Information Systems Lifecycle (ISLC).

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Information System

Resources that enable collection, management, control, and dissemination of information throughout an organization.

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- Database is fun f IS, and its development/u rom perspective of the wider requirements of the n.

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Database System Development Lifecycle (1 of 2)

- Database planning
- System definition
- Requirements c
- Database desig
- DBMS selection (optional)

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Database System Development Lifecycle (2 of 2)

- Application design
- Prototyping (optional)
- Implementation
- Data conversio
- Testing
- Operational maintenance

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Stages of the Database System Development Lifecycle

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Database Planning (1 of 2)

- Management activities that allow stages of database system development lifecycle to be realized as efficiently and effectively as possible.

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- Must be integra gy of the organization.

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Database Planning – Mission Statement

- **Mission statement** for the database project defines major aims of database application.
- Those driving database project normally define the mission statem
- Mission statement helps clarif f the database project and provides clearer p the efficient and effective creation of required database system.

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Database Planning – Mission Objectives

- Once mission statement is defined, **mission objectives** are defined.
- Each objective should identify a particular task that the database must

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- May be accompanied by som information that specifies the work to be done, ces with which to do it, and the money to pay for it all.

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Database Planning (2 of 2)

- Database planning should also include development of standards that govern:
  - how data will be collected,
  - how the for
  - what neces be needed,
  - how design and implemen ld proceed.

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System Definition (1 of 2)

- Describes scope and boundaries of database system and the major user views.
- User view defines what is required of a database system from perspectiv
  - a particular er or Supervisor) or
  - enterprise application area (such as marketing, personnel, or stock control).

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System Definition (2 of 2)

- Database application may have one or more user views.
- Identifying user views helps ensure that no major users of the database are forgotten when developing requirements fo
- User views also help in develo omplex database system allowing req o be broken down into manageable pieces.

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Representation of a Database System with Multiple User Views

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Requirements Collection and Analysis (1 of 4)

- Process of collecting and analyzing information about the part of organization to be supported by the database system, and using this information to identify users' requirements of

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Requirements Collection and Analysis (2 of 4)

- Information is gathered for each major user view including:
  - a description of data used or generated;
  - details of ho nerated;
  - any addition database system.
- Information is analyzed to identify requirements to be included in new database system. Described in the requirements specification.

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Requirements Collection and Analysis (3 of 4)

- Another important activity is deciding how to manage the requirements for a database system with multiple user views.

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- Three main app

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  - centralized

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  - view integration approach;
  - combination of both approaches.

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Requirements Collection and Analysis (4 of 4)

- **Centralized approach**
  - Requirements for each user view are merged into a single set of requirements.
  - A data mod g all user views during the d

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Centralized Approach to Managing Multiple User Views

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Requirements Collection and Analysis (1 of 3)

- **View integration approach**
  - Requirements for each user view remain as separate lists.
  - Data model r view are created and then m tabase design stage.

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Requirements Collection and Analysis (2 of 3)

- Data model representing single user view (or a subset of all user views) is called a **local data model.**
- Each model includes diagrams and documentation describing requu e but not all user views of databa

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Requirements Collection and Analysis (3 of 3)

- Local data models are then merged at a later stage during database design to produce a **global data model,** which represents **all** user views for the database.

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View Integration Approach to Managing Multiple User Views

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Database Design (1 of 4)

- Process of creating a design for a database that will support the enterprise's mission statement and mission objectives for the required database system.

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Database Design (2 of 4)

- Main approaches include:
  - Top-down
  - Bottom-up
  - Inside-out
  - Mixed

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Database Design (3 of 4)

- Main purposes of data modeling include:
  - to assist in understanding the meaning (semantics) of the data;
  - to facilitate e information requirement
- Building data model requires uestions about entities, relationships, and attributes.

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Database Design (4 of 4)

- A data model ensures we understand:
  - each user's perspective of the data;
  - nature of the data itself, independent of its physical representation;
  - use of data

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Criteria to Produce an Optimal Data Model

Structural validity	Consistency with the way the enterprise defines and organizes information.
Simplicity	Ease of understanding by IS professionals and nontechnical users.
Expressibility	Ability to distinguish between different data, relationships b
Nonredundancy	E in particular, the representation of any o mation exactly once.
Shareability	Not specific to any parti or technology and thereby usable by man
Extensibility	Ability to evolve to support new requirements with minimal effect on existing users.
Integrity	Consistency with the way the enterprise uses and manages information.
Diagrammatic representation	Ability to represent a model using an easily understood diagrammatic notation.

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Database Design

- Three phases of database design:
  - Conceptual database design
  - Logical database design
  - Physical da

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Conceptual Database Design

- Process of constructing a model of the data used in an enterprise, independent of **all** physical considerations.

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- Data model is built using the information in users' requirements s

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- Conceptual data model is sou ation for logical design phase.

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Logical Database Design

- Process of constructing a model of the data used in an enterprise based on a specific data model (e.g. relational), but independent of a particular DBMS and other physical c
- Conceptual dat apped on to a logical data model.

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Physical Database Design

- Process of producing a description of the database implementation on secondary storage.
- Describes base relations, file organizations, and indexes used to achieve . Also describes any associated security measures.

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- Tailored to a specific DBMS system.

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Three-Level ANSI-SPARC Architecture and Phases of Database Design

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DBMS Selection

- Selection of an appropriate DBMS to support the database system.

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- Undertaken at any time prior to logical design provided sufficient inform [illegible] ing system requirements.

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- Main steps to selecting a DB
  - define Terms of Reference of study;
  - shortlist two or three products;
  - evaluate products;
  - recommend selection and produce report.

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DBMS Evaluation Features (1 of 4)

Data Definition	Physical Definition
Primary key enforcement	File structures available
Foreign key specification	File structure maintenance
Data types available	Ease of reorganization
Data type extensibility	
Domain specification	h fields/records
Ease of restructuring	D n
Integrity controls	Encryption routines
View mechanism	Memory requirements
Data dictionary	Storage requirements
Data independence	
Underlying data model	
Schema evolution	

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DBMS Evaluation Features (2 of 4)

Accessibility	Transaction Handling
Query language: SQL2/SQL:2011/ODMG compliant	Backup and recovery routines Checkpointing facility
Interfacing to 3GLs	Logging facility
Multi-user	of concurrency
Security	esolution strategy
Access controls	nsaction models
Authorization mechanism	processing

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DBMS Evaluation Features (3 of 4)

Utilities	Development
Performance measuring	4GL/5GL tools
Tuning	CASE tools
Load/unload facilities	abilities
User usage monitoring	ures, triggers, and rules
Database administration support	W nt tools
Other Features	
Upgradability	Interoperability with other DBMSs and other systems
Vendor stability	Web integration
User base	Replication utilities
Training and user support	Distributed capabilities

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DBMS Evaluation Features (4 of 4)

Other Features	
Documentation	Portability
Operating system required	Hardware required
Cost	Network support
Online help	d capabilities
Standards used	A or 3-tier client/server)
Version management	p
Extensibile query optimization	Transaction throughput
Scalability	Maximum number of concurrent users
Support for reporting and analytical tools	XML and Web services support

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Example - Evaluation of DBMS Product

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Application Design

- Design of user interface and application programs that use and process the database.
- Database design and application design are parallel activities.

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- Includes two important activiti
  - transaction design;
  - user interface design.

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Application Design - Transactions (1 of 2)

- An action, or series of actions, carried out by a single user or application program, which accesses or changes content of the database.
- Should define a evel characteristics ired.

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Application Design - Transactions (2 of 2)

- Important characteristics of transactions:
  - data to be used by the transaction;
  - functional characteristics of the transaction;
  - output of th
  - importance
  - expected rate of usage.
- Three main types of transactions: retrieval, update, and mixed.

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Prototyping

- Building working model of a database system.
- Purpose
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  – to identify features of a system that work well, or are inadequate;
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  – to suggest improvements features;
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  – to clarify the users' require
  – to evaluate feasibility of a particular system design.

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Implementation

- Physical realization of the database and application designs.
  - Use DDL to create database schemas and empty database fil
  - Use DDL to er views.
  - Use 3GL or 4GL to create tion programs. This will include the database transactions implemented using the DML, possibly embedded in a host programming language.

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Data Conversion and Loading

- Transferring any existing data into new database and converting any existing applications to run on new database. Assignment Project Exam Help
- Only required w https://eduassistpro.github.io/ em is replacing an old system.
  - DBMS normally has utility Add WeChat edu_assist_pro xisting files into new database.
- May be possible to convert and use application programs from old system for use by new system.

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Testing (1 of 2)

- Process of running the database system with intent of finding errors.
- Use carefully planned test strategies and realistic data.
- Testing cannot t can show only that software faults are presen
- Demonstrates that database a ion programs **appear** to be working according to requirements.

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Testing (2 of 2)

- Should also test usability of system.
- Evaluation conducted against a usability specification.

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- Examples of cri
  – Learnability

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  – Performance;

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  – Robustness;
  – Recoverability;
  – Adaptability.

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Operational Maintenance

- Process of monitoring and maintaining database system following installation.
- Monitoring performance of system.
  - if performan ing or reorganizati
- Maintaining and upgrading da lication (when required).
- Incorporating new requirements into database application.

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CASE Tools (1 of 2)

- Support provided by CASE tools include:
  - data dictionary to store information about database system's data;
  - design tools ... s;
  - tools to per... orate data model, and conceptual and logica... ls;
  - tools to enable prototyping of applications.

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CASE Tools (2 of 2)

- Provide following benefits:
  - Standards;
  - Integration;
  - Support for
  - Consistenc
  - Automation.

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CASE Tools and Database System Development Lifecycle

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Data Administration and Database Administration

- The Data Administrator (DA) and Database Administrator (DBA) are responsible for managing and controlling the corporate data and corporate database, respectively.

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- DA is more con s of database system develop is more concerned with later stages.

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Data Administration

- Management of data resource including:
  - database planning,
  - development and maintenance of standards, policies and proced d logical database design.

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Database Administration

- Management of physical realization of a database system including:
  - physical database design and implementation,
  - setting secu s,
  - monitoring d reorganizing the database.

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Chapter 11

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e Analysis and the **me** Case Study

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Learning Objectives (1 of 3)

11.1 When fact-finding techniques are used in the database application lifecycle.

11.2 The types of facts collected in each stage of the database applica

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11.3 The types of documentatio in each stage of the database application lifecycl

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Learning Objectives (2 of 3)

11.4 The most commonly used fact-finding techniques.

11.5 How to use each fact-finding technique and the advantages and disadvantages of each.

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11.6 About a pro led **DreamHome.**

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Learning Objectives (3 of 3)

11.7 How to apply fact-finding techniques to the early stages of the database application lifecycle.

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Fact-Finding Techniques (1 of 2)

- It is critical to capture the necessary facts to build the required database application.
- These facts are captured using fact-finding techniques.

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- The formal proc such as interviews and questionnaires cts about systems, requirements, and pr

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When Are Fact-Finding Techniques Used?

- Fact-finding used throughout the database application lifecycle. Crucial to the early stages including database planning, system definition, and requirements collection and analysis st
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  https://eduassistpro.github.io/
- Enables develo rminology, problems, opportunities, const irements, and priorities of the organization a s of the system.
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Examples of Data Captured and Documentation Produced During the Database Application Lifecycle (1 of 3)

Stage of Database System Development Lifecycle	Examples of Data Captured	Examples of Documentation Produced
Database planning	Aims and objectives of database project	Mission statement and objectives of database system
System definition	(i ... a	ition of scope and boundary of ase system; definition of user to be supported
Requirements collection and analysis	Requirements for user vie systems specifications, in performance and security requirements	nd system requirements tions
Database design	Users’ responses to checking the conceptual/logical database design; functionality provided by target DBMS	Conceptual/logical database design (includes ER model(s), data dictionary, and relational schema); physical database Design

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Examples of Data Captured and Documentation Produced During the Database Application Lifecycle (2 of 3)

Stage of Database System Development Lifecycle	Examples of Data Captured	Examples of Documentation Produced
Application design	Users' responses to checking interface design	Application design (includes description of programs and user interface)
DBMS selection	F [illegible] t [illegible]	[illegible] luation and recommendations
Prototyping	Users' responses to prototype	[illegible] s' requirements and systems
Implementation	Functionality provided by target DBMS	
Data conversion and loading	Format of current data; data import capabilities of target DBMS	

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Examples of Data Captured and Documentation Produced During the Database Application Lifecycle (3 of 3)

Stage of Database System Development Lifecycle	Examples of Data Captured	Examples of Documentation d
Testing	T	strategies used; analysis of test
Operational maintenance	Performance testing result new or changing user and system requirements	l; analysis of performance results; modified users' requirements and systems specifications

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Fact-Finding Techniques (2 of 2)

- A database developer normally uses several fact-finding techniques during a single database project including:
  - examining documentation
  - interviewing
  - observing t tion
  - research
  - questionnaires

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Examining Documentation

- Can be useful
  - to gain some insight as to how the need for a database arose.
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  - to identify th n associated with the problem
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  - To understand the current
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Examples of Types of Documentation That Should Be Examined

Purpose of Documentation	Examples of Useful Sources
Describes problem and need for database	Internal memos, emails, and minutes of meetings Employee complaints and documents that describe the problem
Describes the part of the enterprise affected by Problem	[illegible]atement and strategic plan Objectives for the [illegible]prise being studied Task/job descripti[illegible] Samples of completed manual forms and reports Samples of completed computerized forms and reports
Describes current system	Various types of flowcharts and diagrams Data dictionary Database system design Program documentation User/training manuals

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Interviewing (1 of 2)

- Most commonly used, and normally most useful, fact-finding technique. Enables collection of information from individuals face-to-face.

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- Objectives incl ifying facts, clarifying facts, getting the end-user involved, identifying requ nd gathering ideas and opinions.

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Advantages and Disadvantages of Interviewing

Advantages	Disadvantages
Allows interviewee to respond freely and openly to questions	Very time-consuming and costly, and therefore may be impractical
Allows interviewee to feel part of project	Success is dependent on ... n skills of interviewer
Allows interviewer to fo... interesting comments made by interviewee	...be dependent on w... erviewees to p... rviews
Allows interviewer to adapt or reword questions during interview	
Allows interviewer to observe interviewee's body language	

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Interviewing (2 of 2)

- There are two types of interviews unstructured and structured.
- Open-ended questions allow the interviewee to respond in any way that
- Closed-ended questions restri to either specific choices or short, direc s.

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Observing the Organization in Operation

- An effective technique for understanding a system.
- Possible to either participate in, or watch, a person perform activities to learn about the system.

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- Useful when va in question or when the complexity of certain the system prevents a clear explanation b sers.

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Advantages and Disadvantages of Using Observation

Advantages	Disadvantages
Allows the validity of facts and data to be Checked	People may knowingly or unknowingly perform differently when being observed
Observer can see exac[illegible] being done	[illegible] erving tasks involving [illegible] s of difficulty or volume n [illegible] nced during that time p [illegible]
Observer can also obtain data describing the physical environment of the task	Some tasks may not always be performed in the manner in which they are observed
Relatively inexpensive	May be impractical
Observer can do work measurements	

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Research

- Useful to research the application and problem.
- Use computer trade journals, reference books, and the Internet (including user groups and bulletin boards).
- Provide informa solved similar problems, plus whether or not ackages exist to solve or even partially solve th

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Advantages and Disadvantages of Using Research

Advantages	Disadvantages
Can save time if solution already exists	Requires access to appropriate sources of information
Researcher can see how others have solved similar problem requirements	May ultimately not help in solving … use problem is not … lsewhere
Keeps researcher up to date with current developments	

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Questionnaires

- Conduct surveys through questionnaires, which are special-purpose documents that allow facts to be gathered from a large number of people while maintaining so [illegible] ponses.
- There are two t [illegible] ly free-format and fixed-format.

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Advantages and Disadvantages of Using Questionnaires

Advantages	Disadvantages
People can complete and return questionnaires at their convenience	Number of respondents can be low, possibly only 5% to 10%
Relatively inexpensive way to gather data from a large numb	Questionnaires may be returned
People more likely to p facts as responses can be kept confidential	de an opportunity to a questions that have b ted
Responses can be tabulated and analyzed quickly	Cannot observe and analyze the respondent's body language

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Using Fact-Finding Techniques – A Worked Example (1 of 7)

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Using Fact-Finding Techniques – A Worked Example (2 of 7)

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Using Fact-Finding Techniques – A Worked Example (3 of 7)

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Using Fact-Finding Techniques – A Worked Example (4 of 7)

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Using Fact-Finding Techniques – A Worked Example (5 of 7)

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Using Fact-Finding Techniques – A Worked Example (6 of 7)

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Using Fact-Finding Techniques – A Worked Example (7 of 7)

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Mission Statement for DreamHome Database System

“The purpose of the **DreamHome** database system is to maintain the data that is used and generated to support the property rentals business for our clients and property owners and to fa nd sharing of information betw

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Mission Objectives for DreamHome Database System

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System Boundary for DreamHome Database System

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Major User Views for DreamHome Database System

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Cross-Reference of User Views with Main Types of Data Used by Each

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Chapter 12

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lationship Modeling

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Learning Objectives

12.1 How to use Entity–Relationship (ER) modeling in database design.

12.2 Basic concepts associated with ER model.

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12.3 Diagrammat ng ER model using Unified Modeling Langua

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12.4 How to identify and resolve with ER models called connection traps.

12.5 How to build an ER model from a requirements specification.

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ER Diagram of Branch User Views of DreamHome

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Concepts of the ER Model

- Entity types
- Relationship types
- Attributes

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Entity Type (1 of 2)

- Entity type
  - Group of objects with same properties, identified by enterprise as having an independent existence.
- Entity occurren
  - Uniquely identifiable objec y type.

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Examples of Entity Types

Physical existence

Staff	Part
Property	Supplier
Customer	

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Conceptual existence

Viewing	Sale
Inspection	Work experience

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ER Diagram of Staff and Branch Entity Types

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Relationship Types

- Relationship type
  - Set of meaningful associations among entity types.

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- Relationship occurrence
  - Uniquely id https://eduassistpro.github.io/ hich includes one occurrence from each part tity type.

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Semantic Net of Has Relationship Type

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ER Diagram of Branch Has Staff Relationship

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Relationship Types (1 of 2)

- Degree of a Relationship
  - Number of participating entities in relationship.

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- Relationship of degree:
  - two is binarhttps://eduassistpro.github.io/
  - three is ternaryAdd WeChat edu_assist_pro
  - four is quaternary.

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Binary Relationship Called POwns

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Ternary Relationship Called Registers

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Quaternary Relationship Called Arranges

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Relationship Types (2 of 2)

- Recursive Relationship
  - Relationship type where **same** entity type participates more than once in **different roles**.

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- Relationships to indicate purpose that ea pe plays in a relationship.

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Recursive Relationship Called Supervises with Role Names

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Entities Associated Through Two Distinct Relationships with Role Names

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Attributes (1 of 4)

- Attribute
  - Property of an entity or a relationship type.

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- Attribute Domain
  - Set of allow ore attributes.

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Attributes (2 of 4)

- Simple Attribute
  - Attribute composed of a single component with an independent existence.
- Composite Attri
  - Attribute composed of mul nents, each with an independent existe

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Attributes (3 of 4)

- Single-valued Attribute
  - Attribute that holds a single value for each occurrence of an entity type.
- Multi-valued Att
  - Attribute that holds multipl each occurrence of an entity typ

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Attributes (4 of 4)

- Derived Attribute
  - Attribute that represents a value that is derivable from value of a related attribute, or set of attributes, not necessarily

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Keys

- Candidate Key
  - Minimal set of attributes that uniquely identifies each occurrence of an entity type.
- Primary Key
  - Candidate key selected to entify each occurrence of an entity typ
- Composite Key
  - A candidate key that consists of two or more attributes.

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ER Diagram of Staff and Branch Entities and Their Attributes

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Entity Type (2 of 2)

- Strong Entity Type
  - Entity type that is **not** existence-dependent on some other entity type.

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- Weak Entity Ty

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  - Entity type that is existenc nt on some other entity type.

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Strong Entity Type Called Client and Weak Entity Type Called Preference

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Relationship Called Advertises with Attributes

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Structural Constraints (1 of 5)

- Main type of constraint on relationships is called **multiplicity**.
- Multiplicity - number (or range) of possible occurrences of an entity type t e occurrence of an associated entit lar relationship.
- Represents policies (called **b es**) established by user or company.

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Structural Constraints (2 of 5)

- The most common degree for relationships is binary.
- Binary relationships are generally referred to as being:
  - one-to-one
  - one-to-many
  - many-to-many (*:*)

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Semantic Net of Staff Manages Branch Relationship Type

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Multiplicity of Staff Manages Branch (1 : 1) Relationship

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Semantic Net of Staff Oversees PropertyForRent Relationship Type

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Multiplicity of Staff Oversees PropertyForRent (1 : *) Relationship Type

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Semantic Net of Newspaper Advertises PropertyForRent Relationship Type

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Multiplicity of Newspaper Advertises PropertyForRent (* : *) Relationship

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Structural Constraints (3 of 5)

- Multiplicity for Complex Relationships
  - Number (or range) of possible occurrences of an entity type in an *n*-ary relationship when other (*n*-1) values are f

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Semantic Net of Ternary Registers Relationship with Values for Staff and Branch Entities Fixed

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Multiplicity of Ternary Registers Relationship

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Summary of Multiplicity Constraints

Alternative Ways To Represent Multiplicity Constraints	Meaning
0..1	Zero or one entity occurrence
1..1 (or just 1)	Exactly one entity occurrence
0..* (or just *)	[illegible] occurrences
1..*	[illegible] occurrences
5..10	Minim[illegible]axi[illegible]um of 10 entity occurr[illegible]
0, 3, 6–8	Zero or three or six, seven, or eight entity occurrences

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Structural Constraints (4 of 5)

- Multiplicity is made up of two types of restrictions on relationships: **cardinality** and **participation.**

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Structural Constraints (5 of 5)

- Cardinality
  - Describes maximum number of possible relationship occurrences for an entity participating in a given relationship
- Participation
  - Determines whether all or entity occurrences participate in a relationship.

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Multiplicity as Cardinality and Participation Constraints

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Problems with ER Models (1 of 2)

- Problems may arise when designing a conceptual data model called **connection traps**.

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- Often due to a misinterpretation of the meaning of certain relationships.

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- Two main types of connection alled **fan traps** and **chasm traps**.

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Problems with ER Models (2 of 2)

- Fan Trap
  - Where a model represents a relationship between entity types, but pathway between certain entity occurrence
- Chasm Trap
  - Where a model suggests t [illegible] e of a relationship between entity types, but pathway does not exist between certain entity occurrences.

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An Example of a Fan Trap

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Semantic Net of ER Model with Fan Trap

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- At which branch office does staff number SG37 work?

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Restructuring ER Model to Remove Fan Trap

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Semantic Net of Restructured ER Model with Fan Trap Removed

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- SG37 works at branch B003.

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An Example of a Chasm Trap

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Semantic Net of ER Model with Chasm Trap

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- At which branch office is property PA14 available?

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ER Model Restructured to Remove Chasm Trap

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Semantic Net of Restructured ER Model with Chasm Trap Removed

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Chapter 13

d Entity-Relationship odeling

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Learning Objectives

13.1 Limitations of basic concepts of the ER model and requirements to represent more complex applications using additional data modeling concepts.

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13.2 Most useful concept of Enhanced ER (E

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specialization/generalization.

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13.3 A diagrammatic technique for displaying specialization/generalization in an EER diagram using UML.

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Enhanced Entity-Relationship Model

- Since 1980s there has been an increase in emergence of new database applications with more demanding requirements.
- Basic concepts sufficient to represent requi complex applications.
- Response is development of additional ‘semantic’ modeling concepts.

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The Enhanced Entity-Relationship Model

- Semantic concepts are incorporated into the original ER model and called the Enhanced Entity-Relationship (EER) model.

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- Examples of ad model is called specialization /

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Specialization / Generalization (1 of 4)

- Superclass
  - An entity type that includes one or more distinct subgroupings of its occurrences.

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- Subclass

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  - A distinct subgrouping of o of an entity type.

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Specialization / Generalization (2 of 4)

- Superclass/subclass relationship is one-to-one (1 : 1).
- Superclass may contain overlapping or distinct subclasses.
- Not all member [illegible] e a member of a subclass.

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Specialization / Generalization (3 of 4)

- Attribute Inheritance
  - An entity in a subclass represents same ‘real world’ object as in superclass, and may possess subclass-specific attri associated with the supercl

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Specialization / Generalization (4 of 4)

- Specialization
  - Process of maximizing differences between members of an entity by identifying their distinguishing characteristi
- Generalization
  - Process of minimizing diff ween entities by identifying their common characteristics.

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AllStaff Relation Holding Details of All Staff

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Specialization/Generalization of Staff Entity into Subclasses Representing Job Roles

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Specialization/Generalization of Staff Entity into Job Roles and Contracts of Employment

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EER Diagram with Shared Subclass and Subclass with Its Own Subclass

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Constraints on Specialization/Generalization (1 of 3)

- Two constraints that may apply to a specialization/generalization:
  - participation constraints
  - disjoint con
- Participation constraint
  - Determines whether every superclass must participate as a member of a subclass.
  - May be **mandatory or optional**.

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Constraints on Specialization/Generalization (2 of 3)

- Disjoint constraint
  - Describes relationship between members of the subclasses and indicates whether member of a superclass , or more than one, subcla
  - May be **disjoint or nondi**

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Constraints on Specialization/Generalization (3 of 3)

- There are four categories of constraints of specialization and generalization:
  - mandatory and disjoint
  - optional an
  - mandatory
  - optional and nondisjoint.

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DreamHome Worked Example - Staff Superclass with Supervisor and Manager Subclasses

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DreamHome Worked Example - Owner Superclass with PrivateOwner and BusinessOwner Subclasses

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DreamHome Worked Example - Person Superclass with Staff, PrivateOwner, and Client Subclasses

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Chapter 14

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Normalization

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Learning Objectives (1 of 3)

14.1 The purpose of normalization.

14.2 How normalization can be used when designing a relational database.

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14.3 The potentia ith redundant data in base relations.

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14.4 The concept of functional d , which describes the relationship between attributes.

14.5 The characteristics of functional dependencies used in normalization.

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Learning Objectives (2 of 3)

14.6 How to identify functional dependencies for a given relation.

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14.7 How functional dependencies identify the primary key for a relation.

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14.8 How to undertake the proc alization.

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14.9 How normalization uses fu endencies to group attributes into relations that are in a known normal form.

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Learning Objectives (3 of 3)

14.10 How to identify the most commonly used normal forms, namely First Normal Form (1NF), Second Normal Form (2NF), and Third Normal Form (3NF).

14.11 The proble tions that break the rules of 1NF,

14.12 How to represent attribute a form as 3NF relations using normalization.

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Purpose of Normalization (1 of 3)

- Normalization is a technique for producing a set of suitable relations that support the data requirements of an enterprise.

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Purpose of Normalization (2 of 3)

- Characteristics of a suitable set of relations include:
  - the **minimal** number of attributes necessary to support the data requirements of the enterprise;
  - attributes wi nship are found in the same re
  - **minimal** redundancy with te represented only once with the important exception of attributes that form all or part of foreign keys.

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Purpose of Normalization (3 of 3)

- The benefits of using a database that has a suitable set of relations is that the database will be:
  - easier for the user to access and maintain the data;
  - take up min he computer.

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How Normalization Supports Database Design

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Data Redundancy and Update Anomalies (1 of 8)

- Major aim of relational database design is to group attributes into relations to minimize data redundancy.

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Data Redundancy and Update Anomalies (2 of 8)

- Potential benefits for implemented database include:
  - Updates to the data stored in the database are achieved with a minimal number of operations thus reducing th nconsistencies.
  - Reduction i required by the base relations thus minimi

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Data Redundancy and Update Anomalies (3 of 8)

- Problems associated with data redundancy are illustrated by comparing the Staff and Branch relations with the StaffBranch relation.

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Data Redundancy and Update Anomalies (4 of 8)

Staff

staffNo	sName	position	salary	branchNo
SL21	John White	Manager	30000	B005
SG37	Ann Be	00		B003
SG14	David F	00		B003
SA9	Mary Howe	Assistan		B007
SG5	Susan Brand	Manage		B003
SL41	Julie Lee	Assistant	9000	B005

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Data Redundancy and Update Anomalies (5 of 8)

Branch

branchNo	bAddress
B005	22 Deer Rd, London
B007	16 Argyll
B003	163 Main

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Data Redundancy and Update Anomalies

StaffBranch

staffNo	sName	position	salary	branchNo	bAddress
SL21	John White	Manager	30000	B005	22 Deer Rd, London
SG37	Ann Beech			B003	163 Main St, Glasgow
SG14	David Ford	Supervisor		03	163 Main St, Glasgow
SA9	Mary Howe	Assistant	9000	B007	16 Argyll St, Aberdeen
SG5	Susan Brand	Manager	24000	B003	163 Main St, Glasgow
SL41	Julie Lee	Assistant	9000	B005	22 Deer Rd, London

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Data Redundancy and Update Anomalies (7 of 8)

- StaffBranch relation has redundant data; the details of a branch are repeated for every member of staff.
- In contrast, the branch information appears only once for each branch in only the branch number (branc taff relation, to represent where each membe located.

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Data Redundancy and Update Anomalies (8 of 8)

- Relations that contain redundant information may potentially suffer from update anomalies.
- Types of update anomalies include
  - Insertion
  - Deletion
  - Modification

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Lossless-Join and Dependency Preservation Properties

- Two important properties of decomposition.
  - **Lossless-join property** enables us to find any instance of the original relation from corresponding instances in
  - **Dependenc ty** enables us to enforce a constraint on the lation by enforcing some constraint the smaller relations.

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Functional Dependencies

- Important concept associated with normalization.
- Functional dependency describes relationship between attributes.

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- For example, if https://eduassistpro.github.io/ f relation R, B is functionally dependent on A (B), if each value of A in R is associated Add WeChat edu_assist_pro one value of B in R.

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Characteristics of Functional Dependencies (1 of 4)

- Property of the meaning or semantics of the attributes in a relation.
- Diagrammatic representation.

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- The **determinant** of a functional dependency refers to the attribute or group of attributes on the left-hand side of the arrow.

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An Example Functional Dependency

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Example Functional Dependency That Holds for All Time (1 of 2)

- Consider the values shown in staffNo and sName attributes of the Staff relation (see Slide 12).
- Based on sample data, the following functional dependencies

  staffNo → sName

  sName → staffNo

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Example Functional Dependency That Holds for All Time (2 of 2)

- However, the only functional dependency that remains true for all possible values for the staffNo and sName attributes of the Staff relation is:

  staffNo → sN

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Characteristics of Functional Dependencies (2 of 4)

- Determinants should have the minimal number of attributes necessary to maintain the functional dependency with the attribute(s) on the right hand-side.
- This requireme **al dependency**.

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Characteristics of Functional Dependencies (3 of 4)

- Full functional dependency indicates that if A and B are attributes of a relation, B is fully functionally dependent on A, if B is functionally dependent on A, but not on any proper subset o

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Example Full Functional Dependency

- Exists in the Staff relation (see Slide 12).

  staffNo, sName → branchNo

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- True - each val s associated with a single value o

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- However, branchNo is also fu ependent on a subset of (staffNo, sName), n o. Example above is a **partial dependency.**

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Characteristics of Functional Dependencies (4 of 4)

- Main characteristics of functional dependencies used in normalization:
  - There is a **one-to-one** relationship between the attribute(s) [illegible] terminant) and those on th[illegible]nctional dependency.
  - Holds for **all** time.
  - The determinant has the **minimal** number of attributes necessary to maintain the dependency with the attribute(s) on the right hand-side.

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Transitive Dependencies

- Important to recognize a transitive dependency because its existence in a relation can potentially cause update anomalies.

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- Transitive depe dition where A, B, and C are attrib hat if A → B and B → C, then C is transitively d n A via B (provided that A is not functio dent on B or C).

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Example Transitive Dependency

- Consider functional dependencies in the StaffBranch relation (see Slide 12).

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StaffNo → sName, position, salary, branchNo, bAddress

branchNo → b https://eduassistpro.github.io/

- Transitive dependency, branc Add WeChat edu_assist_pro dress exists on staffNo via branchNo.

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The Process of Normalization (1 of 4)

- Formal technique for analyzing a relation based on its primary key and the functional dependencies between the attributes of that relation.
- Often executed … ch step corresponds to … which has known properties.

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Identifying Functional Dependencies (1 of 2)

- Identifying all functional dependencies between a set of attributes is relatively simple if the meaning of each attribute and the relationships between the attributes are well understood

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- This informatio the enterprise in the form of discussions with u documentation such as the users' requiremen tion.

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Identifying Functional Dependencies (2 of 2)

- However, if the users are unavailable for consultation and/or the documentation is incomplete then depending on the database application it may be necessary for the database desig sense and/or experience to p ation.

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Example - Identifying a Set of Functional Dependencies for the StaffBranch Relation (1 of 2)

- Examine semantics of attributes in StaffBranch relation (see Slide 12). Assume that position held and branch determine a member of staff's salary.

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Example - Identifying a Set of Functional Dependencies for the StaffBranch Relation (2 of 2)

- With sufficient information available, identify the functional dependencies for the StaffBranch relation as:

staffNo → sName, position, salary, branchNo, bAddress

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branchNo → b

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bAddress → branchNo

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branchNo, position → salary

bAddress, position → salary

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Example - Using Sample Data to Identify Functional Dependencies (1 of 3)

- Consider the data for attributes denoted A, B, C, D, and E in the Sample relation (see Slide 33).
- Important to establish that sample data values shown in relation are rep … le values that can be held by attri … Assume true despite the relatively small am … a shown in this relation.

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Example - Using Sample Data to Identify Functional Dependencies (2 of 3)

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Example - Using Sample Data to Identify Functional Dependencies (3 of 3)

- Function dependencies between attributes A to E in the Sample relation.

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$A \rightarrow C$

$C \rightarrow A$

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$B \rightarrow D$ (fd

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$A, B \rightarrow E$ (fd4)

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Identifying the Primary Key for a Relation Using Functional Dependencies

- Main purpose of identifying a set of functional dependencies for a relation is to specify the set of integrity constraints that must hold on a relation.

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- An important in ider first is the identification of which is selected to be the primary key for the r

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Example - Identify Primary Key for StaffBranch Relation (1 of 2)

- StaffBranch relation has five functional dependencies (see Slide 31).
- The determinants are staffNo, branchNo, bAddress, (branchNo, pos osition).
- To identify all candidate key(s e attribute (or group of attributes) that uniqu s each tuple in this relation.

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Example - Identify Primary Key for StaffBranch Relation (2 of 2)

- All attributes that are not part of a candidate key should be functionally dependent on the key.
- The only candidate key and therefore primary key for StaffBranch rel ther attributes of the relation are on staffNo.

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Example - Identifying Primary Key for Sample Relation

- Sample relation has four functional dependencies (see Slide 31).
- The determinants in the Sample relation are A, B, C, and (A, B). Howeve hat functionally determines all t relation is (A, B).
- (A, B) is identified as the prim this relation.

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The Process of Normalization (2 of 4)

- As normalization proceeds, the relations become progressively more restricted (stronger) in format and also less vulnerable to update anomalies.

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The Process of Normalization (3 of 4)

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The Process of Normalization (4 of 4)

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Unnormalized Form (UNF)

- A table that contains one or more repeating groups.
- To create an unnormalized table
  - Transform the data from the information source (e.g. form) into ta and rows.

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First Normal Form (1NF)

- A relation in which the intersection of each row and column contains one and only one value.

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UNF to 1NF (1 of 2)

- Nominate an attribute or group of attributes to act as the key for the unnormalized table.
- Identify the repeating group(s) in the unnormalized table which repeats f

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UNF to 1NF (2 of 2)

- Remove the repeating group by
  - Entering appropriate data into the empty columns of rows containing the repeating data (‘flattening’ the table).
  - Or by
  - Placing the repeating data a copy of the original key attribute(s) into a separate relation.

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Second Normal Form (2NF) (1 of 2)

- Based on the concept of full functional dependency.
- Full functional dependency indicates that if
  - A and B are attributes of a relation,
  - B is fully de[illegible]tionally dependent on A but not on [illegible]r subset of A.

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Second Normal Form (2NF) (2 of 2)

- A relation that is in 1NF and every non-primary-key attribute is fully functionally dependent on the primary key.

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1NF to 2NF

- Identify the primary key for the 1NF relation.
- Identify the functional dependencies in the relation.
- If partial depen ary key remove them by placin along with a copy of their determinant.

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Third Normal Form (3NF) (1 of 2)

- Based on the concept of transitive dependency.
- Transitive Dependency is a condition where

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  - A, B and C are attributes of a relation such that if $A \rightarrow B$ and

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  - then C is transitively depe through B. (Provided that A is not fun pendent on B or C).

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Third Normal Form (3NF) (2 of 2)

- A relation that is in 1NF and 2NF and in which no non-primary-key attribute is transitively dependent on the primary key.

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2NF to 3NF

- Identify the primary key in the 2NF relation.
- Identify functional dependencies in the relation.

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- If transitive dep rimary key remove them b relation along with a copy of their dominant.

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General Definitions of 2NF and 3NF

- Second normal form (2NF)
  - A relation that is in first normal form and every non-primary-key attribute is fully functionally dependent on **any candid**
- Third normal fo
  - A relation that is in first an ormal form and in which no non-primary-key attribute is transitively dependent on **any candidate key**.

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Chapter 15

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ced Normalization

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Learning Objectives (1 of 4)

15.1 How inference rules can identify a set of **all** functional dependencies for a relation.

15.2 How Inference rules called Armstrong's axioms can identify a **minima** l dependencies from the set of all s for a relation.

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Learning Objectives (2 of 4)

15.3 Normal forms that go beyond Third Normal Form (3NF), which includes Boyce-Codd Normal Form (BCNF), Fourth Normal Form (4NF), and Fifth Normal Form (5NF).

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15.4 How to ident l Form (BCNF).

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15.5 How to represent attributes a report as BCNF relations using normalization.

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Learning Objectives (3 of 4)

15.6 Concept of multi-valued dependencies and Fourth Normal Form (4NF).

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15.7 The problems associated with relations that break the rules of 4NF.

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15.8 How to create 4NF relation lation, which breaks the rules of to 4NF.

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Learning Objectives (4 of 4)

15.9 Concept of join dependency and Fifth Normal Form (5NF).

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15.10 The problems associated with relations that break the rules of 5NF.

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15.11 How to create 5NF relatio elation, which breaks the rules of 5NF.

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More on Functional Dependencies

- The complete set of functional dependencies for a given relation can be very large.
- Important to find an approach that can reduce the set to a manageable si

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Inference Rules for Functional Dependencies (1 of 5)

- Need to identify a set of functional dependencies (represented as X) for a relation that is smaller than the complete set of functional dependencies (represented as Y) for that relati that every functional depe y the functional dependencies in X.

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Inference Rules for Functional Dependencies (2 of 5)

- The set of all functional dependencies that are implied by a given set of functional dependencies X is called the **closure of X**, written X^+ .

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- A set of inferen **ng's axioms**, specifies how n cies can be inferred from given ones.

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Inference Rules for Functional Dependencies (3 of 5)

- Let A, B, and C be subsets of the attributes of the relation R. Armstrong's axioms are as follows:

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     If B is a sub

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  2. **Augmentation**

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     If A → B, then A,C → B,C

  3. **Transitivity**

     If A → B and B → C, then A → C

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Inference Rules for Functional Dependencies (4 of 5)

- Further rules can be derived from the first three rules that simplify the practical task of computing X+. Let D be another subset of the attributes of relation R, then:

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4. **Self-determination**

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   A → A

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5. **Decomposition**

   If A → B,C, then A → B and A → C

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Inference Rules for Functional Dependencies (5 of 5)

6. **Union**

   If $A \rightarrow B$ and $A \rightarrow C$, then $A \rightarrow B,C$

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7. **Composition**

   If $A \rightarrow B$ an https://eduassistpro.github.io/ D

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Minimal Sets of Functional Dependencies (1 of 2)

- A set of functional dependencies Y is covered by a set of functional dependencies X, if every functional dependency in Y is also in X+; that is, every dependency in Y can be infe

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- A set of functio inimal if it satisfies the following conditio
  - Every dependency in X has a single attribute on its right-hand side.

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Minimal Sets of Functional Dependencies (2 of 2)

- We cannot replace any dependency A → B in X with dependency C → B, where C is a proper subset of A, and still have a set of dependencies that is equivalent to X.

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- We cannot r from X and still have a set of dependencie uivalent to X.

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Boyce–Codd Normal Form (BCNF) (1 of 3)

- Based on functional dependencies that take into account all candidate keys in a relation, however BCNF also has additional constraints compared with the general definition of 3N

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- Boyce–Codd n
  - A relation is in BCNF if an ry determinant is a candidate key.

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Boyce–Codd Normal Form (BCNF) (2 of 3)

- Difference between 3NF and BCNF is that for a functional dependency A → B, 3NF allows this dependency in a relation if B is a primary-key attribute and A is not a c BCNF insists that for this depend ion, A must be a candidate key.

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- Every relation in BCNF is also wever, a relation in 3NF is not necessarily in BCNF.

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Boyce–Codd Normal Form (BCNF) (3 of 3)

- Violation of BCNF is quite rare.
- The potential to violate BCNF may occur in a relation that:

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  - contains tw andidate keys;

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  - the candidate keys overla ve at least one attribute in common.

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Review of Normalization (UNF to BCNF) (1 of 5)

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Review of Normalization (UNF to BCNF) (2 of 5)

StaffPropertyInspection

propertyNo	pAddress	iDate	iTime	Comments	staffNo	sName	carReg
PG4	6 Lawrence St, Glasgow	18-Oct-12 22-Apr-13 1-Oct-13	10.00 09.00 12.00	Need to replace crockery In good order	SG37 SG14 SG14	Ann Beech David Ford David Ford	M231 JGR M533 HDR N721 HFR
PG16	5 Novar Dr, Glasgow	22-Apr-13 24-Oct-13	13.00 14.00	Replace living room Good	SG14	David Ford Ann Beech	M533 HDR N721 HFR

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Review of Normalization (UNF to BCNF) (3 of 5)

StaffPropertyInspection

propertyNo	iDate	iTime	pAddress	Comments	staffNo	sName	carReg
PG4	18-Oct-12	10.00	6 Lawrence	Need to	SG37	Ann Beech	M231 JGR
PG4	22-Apr-13	09	St, Glasgow		14	David Ford	M533 HDR
PG4	1-Oct-13	12.00	6 Lawrence St, Glasgow	Da bath		David Ford	N721 HFR
PG16	22-Apr-13	13.00	5 Novar Dr, Glasgow	Replace living room carpet	SG14	David Ford	M533 HDR
PG16	24-Oct-13	14.00	5 Novar Dr, Glasgow	Good condition	SG37	Ann Beech	N721 HFR

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Review of Normalization (UNF to BCNF) (4 of 5)

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Review of Normalization (UNF to BCNF) (5 of 5)

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Fourth Normal Form (4NF) (1 of 5)

- Although BCNF removes anomalies due to functional dependencies, another type of dependency called a multi-valued dependency (MVD) can also cause data redundancy.
- Possible existe [illegible] ndencies in a relation is due to 1NF and can [illegible] ata redundancy.

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Fourth Normal Form (4NF) (2 of 5)

- Multi-valued Dependency (MVD)
  - Dependency between attributes (for example, A, B, and C) in a relation, such that for each value of A there is a s … et of values for C. However, th … d C are independent of each other

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Fourth Normal Form (4NF) (3 of 5)

- MVD between attributes A, B, and C in a relation using the following notation:

$A \rightarrow\!\!\!\rightarrow B$

$A \rightarrow\!\!\!\rightarrow C$

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Fourth Normal Form (4NF) (4 of 5)

- A multi-valued dependency can be further defined as being trivial or nontrivial.

  A MVD $A \twoheadrightarrow B$ in relation R is defined as being trivial if (a) B ... $A \cup$ ... $= R$.

  A MVD is de... if neither (a) nor (b) are satisfied.

  A trivial MVD does not specify a constraint on a relation, while a nontrivial MVD does specify a constraint.

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Fourth Normal Form (4NF) (5 of 5)

- Defined as a relation that is in Boyce-Codd Normal Form and contains no nontrivial multi-valued dependencies.

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4NF - Example

BranchStaffOwner

branchNo	sName	oName
B003	Ann Beech	Carol Farrel
B003		Farrel
B003		urphy
B003	David Ford	phy

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BranchStaff

branchNo	sName
B003	Ann Beech
B003	David Ford

BranchOwner

branchNo	oName
B003	Carol Farrel
B003	Tina Murphy

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Fifth Normal Form (5NF) (1 of 2)

- A relation decompose into two relations must have the lossless-join property, which ensures that no spurious tuples are generated when relations are reunited through a natural join o

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- However, there ompose a relation into more than two rel ough rare, these cases are managed by join de nd fifth normal form (5NF).

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Fifth Normal Form (5NF) (2 of 2)

- Defined as a relation that has no join dependency.

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5NF – Example (1 of 2)

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5NF – Example (2 of 2)

PropertyNo

propertyNo	itemDescription
PG4	Bed
PG4	Chair
PG16	Bed

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ItemSupplier

itemDescription	supplierNo
Bed	S1
Chair	S2
Bed	S2

PropertySupplier

propertyNo	supplierNo
PG4	S1
PG4	S2
PG16	S2

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Chapter 16

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dology Conceptual
bases Design

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Learning Objectives (1 to 3)

16.1 The purpose of a design methodology.

16.2 Database design has three main phases: conceptual, logical, and physical design.

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16.3 How to deco https://eduassistpro.github.io/ design into specific views of the enterprise.

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Learning Objectives (2 to 3)

16.4 How to use Entity–Relationship (ER) modeling to build a conceptual data model based on the data requirements of an enterprise.

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16.5 How to valid … tual model to ensure it is a true … tation of the data requirements enterprise.

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Learning Objectives (3 to 3)

16.6 How to document the process of conceptual database design.

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16.7 End-users play an integral role throughout the process of conceptual dat

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Design Methodology

- A structured approach that uses procedures, techniques, tools, and documentation aids to support and facilitate the process of design.

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Database Design Methodology

- Three main phases
  - Conceptual database design
  - Logical database design
  - Physical da

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Conceptual Database Design

- The process of constructing a model of the data used in an enterprise, independent of **all** physical considerations.

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Logical Database Design

- The process of constructing a model of the data used in an enterprise based on a specific data model (e.g. relational), but independent of a particular DBMS and other physical c

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Physical Database Design

- The process of producing a description of the implementation of the database on secondary storage; it describes the base relations, file organizations, and indexes design t access to the data, and any a traints and security measures.

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Critical Success Factors in Database Design (1 to 2)

- Work interactively with the users as much as possible.
- Follow a structured methodology throughout the data modeling process.
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- Employ a data-
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- Incorporate structural and inte erations into the data models.
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- Combine conceptualization, normalization, and transaction validation techniques into the data modeling methodology.

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Critical Success Factors in Database Design (2 to 2)

- Use diagrams to represent as much of the data models as possible.
- Use a Database Design Language (DBDL) to represent additional data
- Build a data dictionary to supp data model diagrams.
- Be willing to repeat steps.

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Overview Database Design Methodology (1 to 7)

Conceptual database design

- Step 1 Build conceptual data model
  - Step 1.1 Identify entity types
  - Step 1.2 Ide

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  - Step 1.3 Identify and asso tes with entity or relationship types
  - Step 1.4 Determine attribute domains
  - Step 1.5 Determine candidate, primary, and alternate key attributes

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Overview Database Design Methodology (2 to 7)

- Step 1.6 Consider use of enhanced modeling concepts (optional step)
- Step 1.7 Check model for redundancy
- Step 1.8 Va l against user transactions
- Step 1.9 Review conceptu el with user

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Overview Database Design Methodology (3 to 7)

Logical database design for the relational model

- Step 2 Build and validate logical data model
  - Step 2.1 Derive relations for logical data model
  - Step 2.2 Va rmalization
  - Step 2.3 Validate relations er transactions
  - Step 2.4 Define integrity c

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Overview Database Design Methodology (4 to 7)

- Step 2.5 Review logical data model with user
- Step 2.6 Merge logical data models into global model (optional step)
- Step 2.7 Ch

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Overview Database Design Methodology (5 to 7)

Physical database design for relational database

- Step 3 Translate logical data model for target DBMS
  - Step 3.1 Design base relations
  - Step 3.2 De erived data
  - Step 3.3 Design general c

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Overview Database Design Methodology (6 to 7)

- Step 4 Design file organizations and indexes
  - Step 4.1 Analyze transactions
  - Step 4.2 Choose file organization
  - Step 4.3 Ch
  - Step 4.4 Es e

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Overview Database Design Methodology (7 to 7)

- Step 5 Design user views
- Step 6 Design security mechanisms
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- Step 7 Conside trolled redundancy
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- Step 8 Monitor l system
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Step 1 Build Conceptual Data (1 to 3)

- To build a conceptual data model of the data requirements of the enterprise.
  - Model comprises entity types, relationship types, attributes a[illegible]mary and alternate ke[illegible]ints.

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- Step 1.1 Identify entity types
  - To identify the required entity types.
- Step 1.2 Identify relationship types
  - To identify the important relationships that exist between the entity types.

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Step 1 Build Conceptual Data (2 to 3)

- Step 1.3 Identify and associate attributes with entity or relationship types
  - To associate attributes with the appropriate entity or relationship details of each attribute.

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- Step 1.4 Determine attribute d
  - To determine domains for the attributes in the data model and document the details of each domain.

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Step 1 Build Conceptual Data (3 to 3)

- Step 1.5 Determine candidate, primary, and alternate key attributes
  - To identify the candidate key(s) for each entity and if there is mor y, to choose one to be the pri as alternate keys.
- Step 1.6 Consider use of enhanced modeling concepts (optional step)
  - To consider the use of enhanced modeling concepts, such as specialization / generalization, aggregation, and composition.

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Step 1 Build Conceptual Data Model

- Step 1.7 Check model for redundancy
  - To check for the presence of any redundancy in the model and to remove any that does exist.

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- Step 1.8 Valida ainst user transactions
  - To ensure that the concep supports the required transactions.
- Step 1.9 Review conceptual data model with user
  - To review the conceptual data model with the user to ensure that the model is a ‘true’ representation of the data requirements of the enterprise.

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Extract from Data Dictionary for Staff User Views of DreamHome Showing Description of Entities

Entity name	Description	Aliases	Occurrence
Staff	General term describing all staff employed by **DreamHome**.	Employee	Each member of staff works at one particular branch
PropertyForRent	Gener proper		Each property has a single owner and id available at one specific branch, where the property is managed by one member of staff. A property is viewed by many clients and rented by a single client, at any one time.

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First-Cut ER Diagram for Staff User Views of DreamHome

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Extract from Data Dictionary for Staff User Views of DreamHome Showing Description of Relationships

Entity name	Multiplicity	Relationship	Multiplicity	Entity name
Staff	0..1 0..1	**Manages** **Supervises**	0..100 0..10	**PropertyForRent**
PropertyForRent	1..1			**Lease**

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Extract from Data Dictionary for Staff User Views of DreamHome Showing Description of Attributes

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ER Diagram for Staff User Views of Dream Home with Primary Keys Added

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Revised ER Diagram for Staff User Views of Dream Home with Specialization / Generalization

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Example of Removing a Redundant Relationship Called Rents

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Example of a Non-Redundant Relationship FatherOf

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Using Pathways to Check That the Conceptual Model Supports the User Transactions

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Sixth Edition

Chapter 17

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Design for the
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Learning Objectives (1 of 2)

17.1 How to derive a set of relations from a conceptual data model.

17.2 How to validate these relations using the technique of normalization.

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Learning Objectives (2 of 2)

17.3 How to validate a logical data model to ensure it supports the required transactions.

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17.4 How to merge local logical data models based on one or more user vie ata model that

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represents all us

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17.5 How to ensure that the fina ta model is a true and accurate representation of the data requirements of the enterprise.

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Step 2 Build and Validate Logical Data Model (1 of 2)

- To translate the conceptual data model into a logical data model and then to validate this model to check that it is structurally correct using normalization and supports the required transa

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Step 2 Build and Validate Logical Data Model (2 of 2)

- Step 2.1 Derive relations for logical data model
  - To create relations for the logical data model to represent the entities, relationships, and attributes that have b

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Conceptual Data Model for Staff View Showing All Attributes

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Step 2.1 Derive Relations for Logical Data Model (1 of 10)

- **(1) Strong entity types**
  - For each strong entity in the data model, create a relation that includes all the simple attributes of that entity. For composite a constituent simple attributes.

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(2) Weak entity types
  - For each weak entity in the create a relation that includes all the simple attributes of that entity. The primary key of a weak entity is partially or fully derived from each owner entity and so the identification of the primary key of a weak entity cannot be made until after all the relationships with the owner entities have been mapped.

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Step 2.1 Derive Relations for Logical Data Model (2 of 10)

- **(3) One-to-many (1: *) binary relationship types**
  - For each 1: * binary relationship, the entity on the 'one side' of the relationship is designated as the parent entit … any side' is designated … present this relationship, post a copy o … y key attribute(s) of parent entity … lation representing the child entity, to act as a foreign key.

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Step 2.1 Derive Relations for Logical Data Model (3 of 10)

- **(4) One-to-one (1 : 1) binary relationship types**
  - Creating relations to represent a 1 : 1 relationship is more
  - complex as the cardinality cannot be used to identify the parent and child entiti , the participation constraints ar best to represent the relationship b lved into one relation or by creating two relations and py of the primary key from one relation to the oth
  - Consider the following
    - **(a) mandatory** participation on **both** sides of 1 : 1 relationship;
    - **(b) mandatory** participation on **one** side of 1 : 1 relationship;
    - **(c) optional** participation on **both** sides of 1 : 1 relationship;

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Step 2.1 Derive Relations for Logical Data Model (4 of 10)

- **(a) Mandatory participation on both sides of 1 : 1 relationship**
  - Combine entities involved into one relation and choose one of the primary keys of original entities to be primary key of the new relation, while ed as an alternate key.

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- **(b) Mandatory participation on on :1 relationship**
  - Identify parent and child entities pation constraints. Entity with optional participation in relationship is designated as parent entity, and entity with mandatory participation is designated as child entity. A copy of primary key of the parent entity is placed in the relation representing the child entity. If the relationship has one or more attributes, these attributes should follow the posting of the primary key to the child relation.

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Step 2.1 Derive Relations for Logical Data Model (5 of 10)

- **(c) Optional participation on both sides of a 1:1 relationship**
  - In this case, the designation of the parent and child entities find out more about the rela cision to be made one wa

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Step 2.1 Derive Relations for Logical Data Model (6 of 10)

- **(5) One-to-one (1 : 1) recursive relationships**
  - For a 1 : 1 recursive relationship, follow the rules for participation as described above for a 1 : 1 relationship.

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    - mandatory represent the recursive relationship ies of the primary key.

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    - mandatory participation on onl ion to create a single relation with two copies of th , or to create a new relation to represent the relatio w relation would only have two attributes, both copies of the primary key. As before, the copies of the primary keys act as foreign keys and have to be renamed to indicate the purpose of each in the relation.

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    - optional participation on both sides, again create a new relation as described above.

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Step 2.1 Derive Relations for Logical Data Model (7 of 10)

- **(6) Superclass/subclass relationship types**
  - Identify superclass entity as parent entity and subclass entity as the child entity. There are various options on how to represent … or more relations.
  - The selectio… …tion is dependent on a number of factors such … …ntness and participation constraints on t… …s/subclass relationship, whether the subclasses are involved in distinct relationships, and the number of participants in the superclass/subclass relationship.

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Guidelines for Representation of Superclass/Subclass Relationship

Participation Constraint	Disjoint Constraint	Relations Required
Mandatory	Nondisjoint {And}	Single relation (with one or more discriminators to distinguish the type of each tuple)
Optional		Two relations: one relation for superclass and one relation for all subclasses (with one or more riminators to distinguish the e of each tuple)
Mandatory	Disjoint {Or}	Many relations: one relation for each combined superclass/subclass
Optional	Disjoint {Or}	Many relations: one relation for superclass and one for each subclass

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Representation of Superclass/Subclass Relationship Based on Participation and Disjointness (1 of 3)

Option 1 – Mandatory, nondisjoint

AllOwner (ownerNo, address, telNo, fName, lName, bName, bType, contactName, pOwnerFlag, bOwnerFlag)

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Primary Key ownerNo

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Option 2 – Optional, n

Owner (ownerNo, address, telNo)

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Primary Key ownerNo

Owner Details (ownerNo, fName, lName, bName, bType, contactName, pOwnerFlag, bOwnerFlag)

Primary Key ownerNo

Foreign Key ownerNo **references** Owner(ownerNo)

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Representation of Superclass/Subclass Relationship Based on Participation and Disjointness (2 of 3)

Option 3 – Mandatory, disjoint

PriavteOwner (ownerNo, fName, lName, address, telNo)

Primary Key ownerNo

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BusinessOwner (own[illegible]ame, address, telNo)

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Primary Key ownerNo

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Option 4 – Optional, disjoint

Owner (ownerNo, address, telNo)

Primary Key ownerNo

PrivateOwner (ownerNo, fName, lName)

Primary Key ownerNo

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Representation of Superclass/Subclass Relationship Based on Participation and Disjointness (3 of 3)

ForeignKey ownerNo **references** Owner(ownerNo)

BusinessOwner (ownerNo, bName, bType, contactName)

Primary Key ownerNo

ForeignKey ownerNo

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Step 2.1 Derive Relations for Logical Data Model (8 of 10)

- **(7) Many-to-many $(*:*)$ binary relationship types**
  - Create a relation to represent the relationship and include any attributes that are part of the relationship. We post a copy of the p he entities that participate in ew relation, to act as foreign keys. These foreig lso form the primary key of the new relati in combination with some of the attributes of the relationship.

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Step 2.1 Derive Relations for Logical Data Model (9 of 10)

- **(8) Complex relationship types**
  - Create a relation to represent the relationship and include any attributes that are part of the relationship. Post a copy of the primar tities that participate in the compl relation, to act as foreign keys. resent a ‘many’ relationship (for example, nerally will also form the primary key of this n possibly in combination with some of the attributes of the relationship.

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Step 2.1 Derive Relations for Logical Data Model (10 of 10)

- **(9) Multi-valued attributes**
  - Create a new relation to represent multi-valued attribute and include primary key of entity in new relation, to act as a foreign key ... attribute is itself an alternate key ... key of the new relation is th... lued attribute and the primary key of the entity.

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Summary of How to Map Entities and Relationships to Relations (1 of 2)

Entity/Relationship	**Mapping**
Strong entity	Create relation that includes all simple attributes.
Weak entity	Create relation that includes all simple attributes (primary key still has to be identified after the relationship with each owner entity has been
1: * binary relationship	of entity on the "one" side to act elation representing entity on th attributes of relationship are al any' side.
1:1 binary relationship:	
(a) Mandatory participation on both sides	Combine entities into one relation.
(b) Mandatory participation on one side	Post primary key of entity on the "optional" side to act as foreign key in relation representing entity on the "mandatory" side.
(c) Optional participation on both sides	Arbitrary without further information.
Superclass/subclass relationship	See Table 17.1.(see slide 14)

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Summary of How to Map Entities and Relationships to Relations (2 of 2)

Entity/Relationship	**Mapping**
* : * binary relationship, complex Relationship	Create a relation to represent the relationship and include any attributes of . Post a copy of the primary of the owner entities into to act as foreign keys.
Multi-valued attribute	Cr o represent the multi-va d post a copy of the primary key of the owner entity into the new relation to act as a foreign key.

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Relations for the Staff User Views of DreamHome

Staff (staffNo, fName, lName, position, sex, DOB, supervisorStaffNo) **Primary Key** staffNo **Foreign Key** supervisorStaffNo **references** Staff(staffNo)	**PrivateOwner** (ownerNo, fName, lName, address, telNo) **Primary Key** ownerNo
BusinessOwner (ownerNo, bName, bType, contactName, address, telNo) **Primary Key** ownerNo **Alternate Key** bName **Alternate Key** telNo	**Client** (clientNo, fName, lName, telNo, prefType, maxRent, staffNo) **Primary Key** clientNo **Foreign Key** staffNo **references** Staff(staffNo)
PropertyForRent (propertyNo, str rooms, rent, ownerNo, staffN **Primary Key** propertyNo **Foreign Key** ownerNo **references** PrivateOwner(ownerNo) and BusinessOwner(ownerNo) **Foreign Key** staffNo **references** Staff(staffNo)	propertyNo, dateView, comment) No, propertyNo **F** **references** Client(clientNo) **F** **references** PropertyFor)
Lease (leaseNo, paymentMethod, depositPaid, rentStart, rentFinish, clientNo, propertyNo) **Primary Key** leaseNo **Alternate Key** propertyNo, rentStart **Alternate Key** clientNo, rentStart **Foreign Key** clientNo **references** Client(clientNo) **Foreign Key** propertyNo **references** PropertyForRent(propertyNo) **Derived** deposit (PropertyForRent.rent*2) **Derived** duration (rentFinish – rentStart)	

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Step 2.2 Validate Relations Using Normalization

- To validate the relations in the logical data model using normalization.

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Step 2.3 Validate Relations Against User Transactions

- To ensure that the relations in the logical data model support the required transactions.

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Step 2.4 Check Integrity Constraints

- To check integrity constraints are represented in the logical data model. This includes identifying:
  - Required data
  - Attribute do
  - Multiplicity
  - Entity integrity
  - Referential integrity
  - General constraints

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Referential Integrity Constraints for Relations in Staff User Views of DreamHome (1 of 2)

Staff (staffNo, fName, lName, position, sex, DOB, supervisorStaffNo)
Primary Key staffNo
Foreign Key supervisorStaffNo **references** Staff(staffNo) ON UPDATE CASCADE ON DELETE SET NULL

Client (clientNo, fName, lName, telNo, eMail, prefType, maxRent, staffNo)
Primary key clientNo
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Alternate Key eMail
Foreign Key staffNo **references** S ETE NO ACTION

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PropertyForRent (propertyNo, str , staffNo)
Primary key propertyNo
Foreign Key ownerNo **references** PrivateOwner(ownerNo) and erNo) ON UPDATE CASCADE ON DELETE NO ACTION
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Foreign Key staffNo **references** Staff(staffNo) ON UPDATE CASCADE ON DELETE SET NULL

Viewing (clientNo, propertyNo, dateView, comment)
Primary Key clientNo, propertyNo
Foreign Key clientNo **references** Client(clientNo) ON UPDATE CASCADE ON DELETE NO ACTION
Foreign Key propertyNo **references** PropertyForRent(propertyNo) ON UPDATE CASCADE ON DELETE CASCADE

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Referential Integrity Constraints for Relations in Staff User Views of DreamHome (2 of 2)

Lease (leaseNo, paymentMethod, depositPaid, rentStart, rentFinish, clientNo, propertyNo)
Primary Key leaseNo
Alternate Key propertyNo, rentStart
Alternate Key clientNo, rentStart
Foreign Key clientNo **references** Client(clientNo) ON UPDATE CASCADE ON DELETE NO ACTION
Foreign Key propertyNo **references** PropertyForRent(propertyNo) ON UPDATE CASCADE ON DELETE NO ACTION

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Step 2.5 Review Logical Data Model with User

- To review the logical data model with the users to ensure that they consider the model to be a true representation of the data requirements of the enterprise.

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Step 2.6 Merge Logical Data Models into Global Model (Optional Step)

- To merge logical data models into a single global logical data model that represents all user views of a database.

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Step 2.6.1 Merge Local Logical Data Models into Global Model

- To merge local logical data model into a single global logical data model.
- This activities in this step include:
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  - Step 2.6.1 models into global model
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  - Step 2.6.2 Validate global model
  - Step 2.6.3 Review global logical data model with users.

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Step 2.6.1 Merge Logical Data Models into a Global Model (1 of 2)

- **Tasks typically includes:**
  - (1) Review the names and contents of entities/relations and their candidate keys.
  - (2) Review t of relationship
  - (3) Merge entities/relations cal data models
  - (4) Include (without merging) entities/relations unique to each local data model
  - (5) Merge relationships/foreign keys from the local data models.

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Step 2.6.1 Merge Logical Data Models into a Global Model (2 of 2)

- (6) Include (without merging) relationships/foreign keys unique to each local data model.
- (7) Check for missing entities/relations and relationship
- (8) Check f
- (9) Check Integrity Constr
- (10) Draw the global ER/relation diagram
- (11) Update the documentation.

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Step 2.6.2 Validate Global Logical Data Model

- To validate the relations created from the global logical data model using the technique of normalization and to ensure they support the required transactions, if necessary.

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Step 2.6.3 Review Global Logical Data Model with Users

- To review the global logical data model with the users to ensure that they consider the model to be a true representation of the data requirements of an enterprise.

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Relations for the Branch User Views of DreamHome (1 of 2)

Branch (branchNo, street, city, postcode, mgrStaffNo) **Primary Key** branchNo **Alternate Key** postcode **Foreign Key** mgrStaffNo **references** Manager(staffNo)	**Telephone** (telNo, branchNo) **Primary Key** telNo **Foreign Key** branchNo **references** Branch(branchNo)
Staff (staffNo, name, position, salary, supervisor StaffNo, branchNo) **Primary Key** staffNo **Foreign Key** supervisor StaffNo **ref** **Foreign Key** branchNo **references**	**Manager** (staffNo, mgrStartDate, bonus) **Primary Key** staffNo **Foreign Key** staffNo **references** Staff(staffNo)
Private Owner (ownerNo, name, ad **Primary Key** ownerNo	b Name, bType, contactName, a **P** **A**
PropertyForRent (propertyNo, street, city, postcode, type, rooms, rent, ownerNo, staffNo, bName, branchNo) **Primary Key** propertyNo **Foreign Key** ownerNo **references** PrivateOwner(ownerNo) **Foreign Key** bName **references** BusinessOwner(bName) **Foreign Key** staffNo **references** Staff(staffNo) **Foreign Key** branchNo **references** Branch(branchNo)	**Client** (clientNo, name, telNo, prefType, maxRent) **Primary Key** clientNo

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Relations for the Branch User Views of DreamHome (2 of 2)

Lease (leaseNo, paymentMethod, depositPaid, rentStart, rentFinish, clientNo, propertyNo) **Primary Key** leaseNo **Alternate Key** propertyNo, rentStart **Alternate Key** clientNo, rentStart **ForeignKey** clientNo **references** Client(clientNo) **Foreign Key** propertyNo **references** PropertyFor Rent(propertyNo) **Derived** deposit (PropertyForRent.r **Derived** duration (rentFinish - rentS	**Registration** (clientNo, branchNo, staffNo, dateJoined) **Primary Key** clientNo **Foreign Key** clientNo **references** Client(clientNo) **Foreign Key** branchNo **references** Branch(branchNo) **Foreign Key**, staffNo **references** Staff(staffNo)
Advert (propertyNo, newspaperName, dateAdvert, cost) **Primary Key** propertyNo, newspaperName, dateAdvert **Foreign Key** propertyNo **references** PropertyFor Rent(propertyNo) **Foreign Key** newspaper Name **references** Newspaper(newspaperName)	**N** rName, address, telNo, contact N **P** erName **A**

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Relations That Represent the Global Logical Data Model for DreamHome (1 of 2)

Branch (branchNo, street, city, postcode, mgrStaffNo) **Primary Key** branchNo **Alternate Key** postcode **Foreign Key** mgrStaffNo **references** Manager(staffNo)	**Telephone** (telNo, branchNo) **Primary Key** telNo **Foreign Key** branchNo **references** Branch(branchNo)
Staff (staffNo, fName, Name, position, sex, DOB, salary, supervisorStaffNo, branchNo) **Primary Key** staffNo **Foreign Key** supervisorStaffNo **re** **Foreign Key** branchNo **reference**	**Manager** (staffNo, mgrStartDate, bonus) **Primary Key** staffNo **Foreign Key** staffNo **references** Staff(staffNo)
Private Owner (ownerNo, fName, **Primary Key** ownerNo	(ownerNo, bName, bType, contact **P** **Alternate Key** telNo
PropertyForRent (propertyNo, street, city, postcode, type, rooms, rent, ownerNo, staffNo, branchNo) **Primary Key** propertyNo **Foreign Key** ownerNo **references** PrivateOwner(ownerNo) and BusinessOwner(ownerNo) **Foreign Key** staffNo **references** Staff(staffNo) **Foreign Key** branchNo **references** Branch(branchNo)	**Viewing** (clientNo, propertyNo, dateView, comment) **Primary Key** clientNo, propertyNo **Foreign Key** clientNo **references** Client(clientNo) **Foreign Key** propertyNo **references** PropertyFor Rent(propertyNo)

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Relations That Represent the Global Logical Data Model for DreamHome (2 of 2)

Client (clientNo, fName, lName, telNo, eMail, prefType, maxRent) **Primary Key** clientNo	**Registration** (clientNo, branchNo, staffNo, dateJoined) **Primary Key** clientNo **Foreign Key** clientNo **references** Client(clientNo) **Foreign Key** branchNo **references** Branch(branchNo) **Foreign Key** staffNo **references** Staff(staffNo)
Lease (leaseNo, paymentMethod, depositPaid, rentStart, rentFinish, clientNo, propertyNo) **Primary Key** leaseNo **Alternate Key** propertyNo, rentSta **Alternate Key** clientNo, rentStart **Foreign Key** clientNo **references** Client(clientNo) **Foreign Key** propertyNo **references** PropertyFor-Rent(propertyNo) **Derived** deposit (PropertyForRent.rent*2) **Derived** duration (rentFinish – rentStart)	**Newspaper** (newspaperName, address, telNo, contact Name) paper Name o
Advert (propertyNo, newspaperName, dateAdvert, cost) **Primary Key** propertyNo, newspaperName, dateAdvert) **Foreign Key** propertyNo Name references PropertyFor Rent Newspaper(property No) **Foreign Key** newspaperName **references** PropertyFor Rent Newspaper(property No)	

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Global Relation Diagram for DreamHome

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Chapter 18

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dology – Physical
se Design for
nal Databases

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Learning Objectives (1 of 2)

18.1 Purpose of physical database design.

18.2 How to map the logical database design to a physical database design.

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18.3 How to desi … et DBMS.

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18.4 How to design general con … target DBMS.

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Learning Objectives (2 of 2)

18.5 How to select appropriate file organizations based on analysis of transactions.

18.6 When to use secondary indexes to improve performance.

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18.7 How to estimate the size of se.

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18.8 How to design user views.

18.9 How to design security mechanisms to satisfy user requirements.

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Logical v. Physical Database Design

- Sources of information for physical design process includes logical data model and documentation that describes model.
- Logical databas ith the **what**, physical databa with the **how**.

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Physical Database Design

- Process of producing a description of the implementation of the database on secondary storage.
- It describes the base relations, file organizations, and indexes used to s to the data, and any associated security measures.

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Overview of Physical Database Design Methodology (1 of 3)

- Step 3 Translate logical data model for target DBMS
  - Step 3.1 Design base relations
  - Step 3.2 Design representation of derived data
  - Step 3.3 De

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Overview of Physical Database Design Methodology (2 of 3)

- Step 4 Design file organizations and indexes
  - Step 4.1 Analyze transactions
  - Step 4.2 Choose file organizations
  - Step 4.3 Ch
  - Step 4.4 Es ements

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Overview of Physical Database Design Methodology (3 of 3)

- Step 5 Design user views
- Step 6 Design security mechanisms
- Step 7 Conside trolled redundancy
- Step 8 Monitor stem

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Step 3 Translate Logical Data Model for Target DBMS

To produce a relational database schema from the logical data model that can be implemented in the target DBMS.

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- Need to know functionality of target DBMS such as how to create base r[illegible]e system supports the definition of

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  - PKs, FKs, and AKs;
  - required data – i.e. whether system supports NOT NULL;
  - domains;
  - relational integrity constraints;
  - general constraints.

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Step 3.1 Design Base Relations (1 of 2)

To decide how to represent base relations identified in logical model in target DBMS.

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- For each relation, need to define:
  - the name of
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  - a list of simple attributes in
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  - the PK and, where approp nd FKs.
  - referential integrity constraints for any FKs identified.

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Step 3.1 Design Base Relations (2 of 2)

- From data dictionary, we have for each attribute:
  - its domain, consisting of a data type, length, and any constraints on the domain;
  - an optional ibute;
  - whether it c
  - whether it is derived, and i should be computed.

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DBDL for the PropertyForRent Relation

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Step 3.2 Design Representation of Derived Data (1 of 2)

To decide how to represent any derived data present in logical data model in target DBMS.

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- Examine logical data model and data dictionary, and produce list of

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- Derived attribute can be store se or calculated every time it is needed.

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Step 3.2 Design Representation of Derived Data (2 of 2)

- Option selected is based on:
  - additional cost to store the derived data and keep it consistent with operational data from which it is derived;
  - cost to calc … uired.
- Less expensive option is chos … to performance constraints.

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PropertyForRent Relation and Staff Relation with Derived Attribute noOfProperties (1 of 2)

PropertyForRent

propertyNo	street	city	postcode	type	Rooms	rent	ownerNo	staffNo	branchNo
PA14	16 Holhead	Aberdeen	AB7 5SU	House	6	650	CO46	SA9	B007
PL94	6 Argyll St	London	NW2	Flat	4	400	CO87	SL41	B005
PG4	6 Lawrence St	Gla					CO40	SL41	B003
PG36	2 Manor Rd	Gla					CO93	SG37	B003
PG21	18 Dale Rd	Glasgow	G12	House			CO87	SG37	B003
PG16	5 Novar Dr	Glasgow	G12 9AX	Flat			CO93	SG14	B003

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PropertyForRent Relation and Staff Relation with Derived Attribute noOfProperties (2 of 2)

Staff

staffNo	fName	lName	branchNo	noOfProperties
SL21	John	White	B005	0
SG37	Ann			2
SG14	David			1
SA9	Mary	Howe		
SG5	Susan	Brand		
SL41	Julie	Lee	B005	1

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Step 3.3 Design General Constraints

To design the general constraints for target DBMS.

- Some DBMS provide more facilities than others for defining enterprise constraints. Example:

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```
CONSTRAINT St                              h
        CHECK (NOT EXIST               staffNo
               FROM Propert
               GROUP BY staffNo
               HAVING COUNT(*) > 100))
```

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Step 4 Design File Organizations and Indexes

To determine optimal file organizations to store the base relations and the indexes that are required to achieve acceptable performance; that is, the way in which relations and tuples will be age.

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- Must understan that database must support.

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Step 4.1 Analyze Transactions (1 of 4)

To understand the functionality of the transactions that will run on the database and to analyze the important transactions.

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- Attempt to iden … such as:

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  - transactions … will have a significant impact on perfo…

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  - transactions that are critical to the business;
  - times during the day/week when there will be a high demand made on the database (called the **peak load).**

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Step 4.1 Analyze Transactions (2 of 4)

- Use this information to identify the parts of the database that may cause performance problems.
- Also need to know high-level functionality of the transactions, su
  - attributes th
  - search criteria used in a q

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Step 4.1 Analyze Transactions (3 of 4)

- Often not possible to analyze all transactions, so investigate most ‘important’ ones.
- To help identify these can use:

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  - **transaction** **ce matrix,** showing rel tion accesses, and/or

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  - **transaction usage map,** indicating which relations are potentially heavily used.

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Step 4.1 Analyze Transactions (4 of 4)

- To focus on areas that may be problematic:
  1. Map all transaction paths to relations.
  2. Determine which relations are most frequently accessed b
  3. Analyze the ransactions that involve these relations.

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Cross-Referencing Transactions and Relations

Table 17.1 Cross-referencing transactions and relations.

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I = Insert; R = Read; U = Update; D = Delete

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Example Transaction Usage Map

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Figure 17.4 Example Transaction Analysis Form

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Step 4.2 Choose File Organizations

To determine an efficient file organization for each base relation.

- File organizations include Heap, Hash, Indexed Sequential Acc –Tree, and Clusters.
- Some DBMSs may not allow file organizations.

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Step 4.3 Choose Indexes (1 of 4)

To determine whether adding indexes will improve the performance of the system.

- One approach is to keep tuples unordered and create as many **seconda** ry.

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Step 4.3 Choose Indexes (2 of 4)

- Another approach is to order tuples in the relation by specifying a **primary** or **clustering index**.

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- In this case, choose the attribute for ordering or clustering the tuples as:

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  – attribute th join operations - this makes join operation nt, or

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  – attribute that is used most often to access the tuples in a relation in order of that attribute.

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Step 4.3 Choose Indexes (3 of 4)

- If ordering attribute chosen is key of relation, index will be a **primary index**; otherwise, index will be a **clustering index**.

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- Each relation c mary index or a clustering index

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- Secondary indexes provide a for specifying an additional key for a base relation that can be used to retrieve data more efficiently.

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Step 4.3 Choose Indexes (4 of 4)

- Have to balance overhead involved in maintenance and use of secondary indexes against performance improvement gained when retrieving data.

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- This includes:

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  – adding an in dary index whenever tuple is inserted;

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  – updating secondary index w nding tuple updated;
  – increase in disk space needed to store secondary index;
  – possible performance degradation during query optimization to consider all secondary indexes.

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Step 4.3 Choose Indexes – Guidelines for Choosing 'Wish-List' (1 of 2)

1. Do not index small relations.
2. Index PK of a relation if it is not a key of the file organization.
3. Add secondar quently accessed.
4. Add secondary index to any avily used as a secondary key.
5. Add secondary index on attributes involved in: selection or join criteria; ORDER BY; GROUP BY; and other operations involving sorting (such as UNION or DISTINCT).

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Step 4.3 Choose Indexes – Guidelines for Choosing ‘Wish-List’ (2 of 2)

6. Add secondary index on attributes involved in built-in functions.
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7. Add secondary index on attributes that could result in an index-only pla
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8. Avoid indexing an attribute o at is frequently updated.
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9. Avoid indexing an attribute if the query will retrieve a significant proportion of the relation.
10. Avoid indexing attributes that consist of long character strings.

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Step 4.4 Estimate Disk Space Requirements

To estimate the amount of disk space that will be required by the database.

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Step 5 Design User Views

To design the user views that were identified during the Requirements Collection and Analysis stage of the database system development lifecycle.

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Step 6 Design Security Measures

To design the security measures for the database as specified by the users.

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Chapter 9

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Relational DBMSs

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Learning Objectives (1 of 2)

9.1 Requirements for advanced database applications.

9.2 Why RDBMSs currently are not well suited to supporting such applications.

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9.3 Problems ass https://eduassistpro.github.io/ cts in a RDB.

9.4 Object-oriented features in Add WeChat edu_assist_pro

- row types;
- user-defined types and user-defined routines;
- polymorphism;
- inheritance;

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Learning Objectives (2 of 2)

- reference types and object identity;
- collection types (ARRAYs, MULTISETs, SETs, and LISTs);Assignment Project Exam Help
- extensions t make it computatio https://eduassistpro.github.io/
- triggers; Add WeChat edu_assist_pro
- BLOBs and CLOBs;
- recursion.

9.5 Object-oriented extensions to Oracle.

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Advanced Database Applications (1 of 2)

- Computer-Aided Design/Manufacturing (CAD/CAM)
- Computer-Aided Software Engineering (CASE)
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- Network Manag
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- Office Informati ultimedia Systems
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- Digital Publishing
- Geographic Information Systems (GIS)
- Interactive and Dynamic Web sites

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Computer-Aided Design (CAD)

- Stores data relating to mechanical and electrical design, for example, buildings, airplanes, and integrated circuit chips.
- Designs of this type have some common characteristics:
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  - Data has ma ll number of instances.
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  - Designs may be very large.
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  - Design is not static but evolves through time.
  - Updates are far-reaching.
  - Involves version control and configuration management.
  - Cooperative engineering.

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Advanced Database Applications (2 of 2)

- Computer-Aided Manufacturing (CAM)
  - Stores similar data to CAD, plus data about discrete production.
- Computer-Aide (CASE)
  - Stores data about stages development lifecycle.

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Network Management Systems

- Coordinate delivery of communication services across a computer network.
- Perform such tasks as network path management, problem manag nning.
- Systems handle complex data e real-time performance and continuous
- To route connections, diagnose problems, and balance loadings, systems have to be able to move through this complex graph in real-time.

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Office Information Systems (OIS) and Multimedia Systems

- Stores data relating to computer control of information in a business, including electronic mail, documents, invoices, and so on. Assignment Project Exam Help
- Modern system text, photographs, diagrams, audi
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- Documents may have specific perhaps described using mark-up language such as SGML, HTML, or XML.

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Digital Publishing

- Can store books, journals, papers, and articles electronically and deliver them over high-speed networks to consumers.

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- Can also handl consisting of text, audio, image, a ation.

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- Amount of information availab online is in the order of petabytes (10^{15} bytes), making them largest databases DBMS has ever had to manage.

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Geographic Information Systems (GIS)

- GIS database stores spatial and temporal information, such as that used in land management and underwater exploration.
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- Much of data is d satellite photographs, a .
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- Searches may involve identifyi based, for example, on shape, color, or texture, using advanced pattern-recognition techniques.

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Interactive and Dynamic Web Sites

- Online catalog for selling clothes maintains preferences for previous visitors and allows visitor to:
  - obtain 3D rendering of any item based on color, size, fabric, etc.;
  - modify rend [illegible] ement, illumination, backdrop, occ [illegible]
  - select accessories to go with the outfit, from items presented in a sidebar;
- Need to handle multimedia content and to interactively modify display based on user preferences and user selections. Added complexity of providing 3D rendering.

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Weaknesses of RDBMSs (1 of 5)

- Poor Representation of "Real World" Entities
  - Normalization leads to relations that do not correspond to entities in "real world".
- Semantic Overl
  - Relational model has only uct for representing data and dat ips: the relation.
  - Relational model is **semantically overloaded**.

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Weaknesses of RDBMSs (2 of 5)

- Poor Support for Integrity and General Constraints
- Homogeneous Data Structure
  - Relational model assumes both horizontal and vertical hom
  - Many RDBMSs now allow **rge Objects (BLOBs).**

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Weaknesses of RDBMSs (3 of 5)

- Limited Operations
  - RDBMSs only have a fixed set of operations which cannot be extended.

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- Difficulty Handli

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  - Extremely difficult to produ e queries.

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  - Extension proposed to rel bra to handle this type of query is unary transitive (recursive) closure operation.

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Example - Recursive Query

staffNo	managerstaffNo
S005	S004
S004	S003
S003	S002
S002	S001
S001	NULL

(a)

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staffNo	managerstaffNo
S005	S004
S004	S003
S003	S002
	1
LL	
S	
S005	S002
S005	S001
S004	S002
S004	S001
S003	S001

(b)

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Weaknesses of RDBMSs (4 of 5)

- Impedance Mismatch
  - Most DMLs lack **computational completeness**.
  - To overcome this, SQL can be embedded in a high-level 3GL.
  - This produc atch - mixing different programming par
  - Estimated that as much as 30% of programming effort and code space is expended on this type of conversion.

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Weaknesses of RDBMSs (5 of 5)

- Other Problems with RDBMSs
  - Transactions are generally short-lived and concurrency control protocols not suited for long-lived transactions
  - Schema ch
  - RDBMSs are poor at navi ess.

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Storing Objects in Relational Databases (1 of 2)

- One approach to achieving persistence with an OOPL is to use an RDBMS as the underlying storage engine.
- Requires mapping class instances (i.e. objects) to one or more tuples dis e relations.
- To handle class hierarchy, ha cs tasks to perform:

(1) design relations to represent class hierarchy;

(2) design how objects will be accessed.

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Storing Objects in Relational Databases (2 of 2)

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Mapping Classes to Relations (1 of 2)

Number of strategies for mapping classes to relations, although each results in a loss of semantic information.

(1) Map each class or subclass to a relation:

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Staff (**staffNo** n, sex, DOB, salary)

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Manager (**staffNo**, bonus, m)

SalesPersonnel (**staffNo**, salesArea, carAllowance)

Secretary (**staffNo**, typingSpeed)

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Mapping Classes to Relations (2 of 2)

(2) Map each subclass to a relation

Manager (**staffNo**, fName, lName, position, sex, DOB, salary, bonus, mgrStartDate)

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SalesPersonnel (osition, sex, DOB, salary, salesArea

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Secretary (**staffNo**, fName, lNam sex, DOB, salary, typingSpeed)

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(3) Map the hierarchy to a single relation

Staff (**staffNo**, fName, lName, position, sex, DOB, salary, bonus, mgrStartDate, salesArea, carAllowance, typingSpeed, typeFlag)

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ORDBMSs

- RDBMSs currently dominant database technology with estimated sales of U S$24billion in 2011, expected to grow to US$37billion by 2016.

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- Vendors of RDBM romise of OODBMS.

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- Agree that RDBM anced database applications, and added functionalit

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- Reject claim that extended RDBMS ide sufficient functionality or will be too slow to cope adequately with new complexity.
- Can remedy shortcomings of relational model by extending model with OO features.

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ORDBMSs – Features (1 of 2)

- OO features being added include:
  - user-extensible types,
  - encapsulation,
  - inheritance,
  - polymorphis
  - dynamic binding of metho
  - complex objects including non-1NF objects,
  - object identity.

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ORDBMSs – Features (2 of 2)

- However, no single extended relational model.
- All models:
  - share basic relational tables and query language,
  - all have so
  - some can store methods (es or triggers).
- Some analysts predict ORDBMS will have 50% larger share of market than RDBMS.

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Stonebraker's View

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Advantages of ORDBMSs

- Resolves many of known weaknesses of RDBMS.
- Reuse and sharing:
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  – reuse comes from ability to extend server to perform standard fu
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  – gives rise to increased pro th for developer and end-user.
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- Preserves significant body of knowledge and experience gone into developing relational applications.

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Disadvantages of ORDBMSs

- Complexity.
- Increased costs.

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- Proponents of r ve simplicity and purity of relatio

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- Some believe RDBMS is bein for what will be a minority of applications.

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- OO purists not attracted by extensions either.
- SQL now extremely complex.

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SQL:2011 - New OO Features

- Type constructors for row types and reference types.
- User-defined types (distinct types and structured types) that can participate in supertype/subtype relationships.

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- User-defined pr https://eduassistpro.github.io/ thods, and operators.

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- Type constructors for collectio ays, sets, lists, and multisets).
- Support for large objects – BLOBs and CLOBs.
- Recursion.

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Row Types

- Sequence of field name/data type pairs that provides data type to represent types of rows in tables.
- Allows complete rows to be:
  - stored in va
  - passed as arguments to ro
  - returned as return values f n calls.
- Also allows column of table to contain row values.

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Example 9.1 Use of Row Type

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User-Defined Types (UDTs) (1 of 2)

- SQL:2011 allows definition of UDTs.
- May be used in same way as built-in types.

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- Subdivided into types and structured type https://eduassistpro.github.io/
- Distinct type allows differentia n same Add WeChat edu_assist_pro underlying base types:

CREATE TYPE OwnerNoType AS VARCHAR(5)
FINAL;

CREATE TYPE StaffNoType AS VARCHAR(5) FINAL;

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User-Defined Types (UDTs) (2 of 2)

- Would get error if attempt to treat instance of one type as instance of other type.
- Not same as SQL domains, which constrains set of valid values that can b
- Generally, UDT r more attribute definitions.
- Definition also consists of routine declarations (operator declarations deferred).
- Can also define equality and ordering relationships using CREATE ORDERING FOR.

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UDTs – Encapsulation and get/set Functions

- Value of an attribute can be accessed using common dot notation:

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p.fName   p.fName = 'A. Smith'

- SQL encapsula https://eduassistpro.github.io/ h an observer (get) and a mutator (set) functi

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- These functions can be redefined by user in UDT definition.

```
FUNCTION fName(p PersonType) RETURNS VARCHAR(15)
     RETURN p.fName;
```


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UDTs – Constructors and NEW Expression

- (Public) constructor function is automatically defined to create new instances of type:

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- The constructor e as type, takes 0 arguments, and returns a new ith attributes set to their default values.

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- User-defined constructor methods can be provided to initialize new instances. Must have same name as UDT but different parameters to public constructor

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UDTs - Example Constructor Method

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Example 9.2 - Definition of New UDT (1 of 2)

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Example 9.2 - Definition of New UDT (2 of 2)

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Subtypes and Supertypes

- UDTs can participate in subtype/supertype hierarchy using UNDER clause.
- Multiple inheritance is not supported.
- Subtype inherit ehavior of its supertypes.
- Can define additional attribute ods and can override inherited methods.
- Concept of substitutability supported: whenever instance of supertype expected instance of subtype can be used in its place.

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Example 9.3 - Creation of Subtype (1 of 2)

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Example 9.3 - Creation of Subtype (2 of 2)

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User-Defined Routines (UDRs) (1 of 4)

- UDRs define methods for manipulating data.
- UDRs may be defined as part of a UDT or separately as part of a schema.

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- An SQL-invoke edure, function, or method.

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- May be externally provided in rogramming language or defined completely in SQL.

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User-Defined Routines (UDRs) (2 of 4)

- An SQL-invoked procedure is invoked from SQL CALL statement.
- May have zero or more parameters, each of which may be IN, OUT, or fined fully within SQL.

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- An SQL-invoked function retu .
- Any specified parameters must be input parameters with one designated as result parameter (using RESULT keyword).

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User-Defined Routines (UDRs) (3 of 4)

- SQL-invoked method is similar to a function but:
  - method is associated with a single UDT;
  - signature of every method of a UDT must be specified in UDT and def ecify UDT.

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- Three types of m
  - constructor methods, invoke ;

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  - instance methods, invoked using dot notation or using generalized invocation format;

    e.g. p.fName or (p AS StaffType).fName();

- static methods (analogous to class methods), invoked using ::; e.g. StaffType :: totalStaff().

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User-Defined Routines (UDRs) (4 of 4)

- External routine defined by specifying an external clause that identifies ‘compiled code’ in operating system’s file storage.

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- ORDBMS will namically link this object file into t be invoked when required.

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- Procedure for this is outside bounds of SQL standard and is left as implementation-defined.

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Polymorphism

- Routine names may be overloaded, provided:
  - no two functions in same schema have same signature;
  - no two procedures in same schema have same name and number of p
- Overriding applie ly based on runtime value of SELF argument.
- SQL:2011 uses generalized object model, so types of all arguments considered when deciding which routine to invoke (left to right).
- Precedence lists used to determine closest match.

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Reference Types and Object Identity (1 of 2)

- In SQL:2011, reference types can be used to define relationships between row types and uniquely identify a row within a table.
- Reference type ... one table and used as a direc... row in some base table defined to be of this type ... pointer type in ‘C’/C++).
- In this way, reference type provides similar functionality as OID of OODBMSs.

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Reference Types and Object Identity (2 of 2)

- Thus, references allow a row to be shared among multiple tables, and enable users to replace complex join definitions in queries with much simpler path expressions.

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- References als ive way to navigate data i sed joins.

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- REF IS SYSTEM GENERATE TE TYPE indicates that actual values of associated REF type are provided by the system.

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Example 9.4 Table Creation based on UDT

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- or

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Subtables and Supertables

- No mechanism to store all instances of given UDT, unless user explicitly creates a single table in which all instances are stored.

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- Thus, in SQL:2 to apply an SQL query to all inst

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- Can use table inheritance, wh able to be created that inherits all the attributes of one or more existing tables using UNDER clause.
- Subtable/supertable independent from UDT inheritance facility.

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Example 9.5 Creation of Subtable

CREATE TABLE Staff OF StaffType UNDER Person;

- Each row of supertable Person can correspond to at most one row in Staff.

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- Each row in St

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e corresponding row in Person.

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- Containment used: row of sub ined' in one of its supertables.

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Example 9.6 Using Reference Type to Define a Relationship

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Example 9.7 Retrieve Specific Column/ Rows

Find the names of all Managers.

SELECT s.lName

FROM Staff s

WHERE s.po

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- Uses implicitly defined observ position.

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Example 9.8 Invoke User-Defined Function

Find the names and ages of all Managers.

SELECT s.lName, s.age

FROM Staff s

WHERE s.is

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- Uses user-defined function is s a predicate of the WHERE clause (returns T ber of staff is a manager).
- Also uses inherited virtual observer function age.

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Example 9.9 Use of ONLY (1 of 2)

Find names of all people over 65.

```
SELECT p.lName, p.fName
FROM Person p
WHERE p.ag
```

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- This will list out not only recor inserted into Person table, but also records rectly/indirect into subtables of Person.

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Example 9.9 Use of ONLY (2 of 2)

- Can restrict access to specific instances of Person table, excluding any subtables, using ONLY.

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```
SELECT p.lN
FROM ONLY
WHERE p.age > 65;
```

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Example 9.10 Use of Dereference Operator (1 of 2)

Find name of member of staff who manages property PG4.

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- In SQL2, this query would have required a join or nested subquery

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Example 9.10 Use of Dereference Operator (2 of 2)

To retrieve the member of staff for property PG4, rather than just the first and last name:

```
SELECT DEREF(p.staffID) AS Staff
FROM Prope
WHERE p.propertyNo = 'P
```

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- Note, reference types by them ot provide referential integrity.

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Collection Types (1 of 2)

- Collections are type constructors used to define collections of other types.
- Used to store multiple values in single column and can result in nested tables.
- SQL:2011 has p MULTISET collection types.
- Later SQL may have parameterized LIST and SET collection types.
- The parameter may be predefined type, UDT, row type, or another collection (but not reference type or UDT containing reference type).

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Collection Types (2 of 2)

ARRAY: 1D array with maximum number of elements.

LIST: ordered collection that allows duplicates.

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SET: unordered allow duplicates.

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MULTISET: unor ws duplicates.

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- Similar to those in the ODMG rd.

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Example 9.11 Use of ARRAY Collection

- Branch has up to three telephone numbers:

telNo. VARCHAR(13) ARRAY[3]

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Retrieve first and 003.

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Multiset

- Unordered collection of elements, all of same type, with duplicates permitted.
- Since multiset is unordered there is no ordinal position to reference indivi rrays, multiset is an unbounded
- Analogous to tables, operator ed to convert multiset to table (UNNEST) and table to multiset (MULTISET).

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Operations on MULTISET (1 of 2)

- SET, removes duplicates from a multiset to produce a set.
- CARDINALITY, returns number of current elements.
- ELEMENT, retu [illegible] t if multiset only has one element (or null if mul [illegible] o elements). Exception raised if multiset ha [illegible] n one element.

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Operations on MULTISET (2 of 2)

- MULTISET UNION, computes union of two multisets; keywords ALL or DISTINCT can retain duplicates or remove them.

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- MULTISET INT … rsection of two multisets; keyw … ve duplicates; keyword ALL can place in res … instances of each value as minimum numb … ces of that value in either operand.

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- MULTISET EXCEPT, computes difference of two multisets; again, keyword DISTINCT or ALL can be specified.

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Aggregate Functions for MULTISET

- COLLECT, creates multiset from value of the argument in each row of a group;
- FUSION, creates multiset union of a multiset value in all rows of a group
- INTERSECTION, creates mul ction of a multiset value in all rows of a

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Predicates for use with MULTISET

- Comparison predicate (equality and inequality only);
- DISTINCT predicate;

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- MEMBER predi

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- SUBMULTISET whether one multiset is a submultiset of an

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- IS A SET/IS NOT A SET predicate, which checks whether a multiset is a set.

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Example 9.12 Use of Collection MULTISET

- Extend Staff table to contain details of next-of-kin:

nok NameType MULTISET

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Find first and la ’s next of kin.

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Example 9.13 FUSION and INTERSECTION (1 of 2)

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```
SELECT FUSION(viewDates) AS viewDateFusion,
    INTERSECTION(viewDates) AS viewDateIntersection
FROM PropertyViewDates;
```


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Example 9.13 FUSION and INTERSECTION (2 of 2)

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Example 9.14 Typed Views

```
CREATE VIEW FemaleView OF
        PersonType (REF IS personID DERIVED)
    AS SELECT fName, lName
    FROM ONLY (P
    WHERE sex = 'F
CREATE VIEW FemaleStaff3View OF
        StaffType UNDER FemaleVie
    AS SELECT fName, lName, staffNo, position
    FROM ONLY (Staff)
    WHERE branchNo = 'B003';
```

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Persistent Stored Modules (SQL/PSM) (1 of 2)

- SQL:2011 has some new statement types to make it computationally complete.
- Behavior (methods) can be stored and executed from within database

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- Can group statements into a c tatement (block), with its own local varia

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Persistent Stored Modules (SQL/PSM) (2 of 2)

- Some of the new statements are:
  - An assignment statement.
  - An IF … THEN … ELSE … END IF statement.
  - CASE state
  - A set of stat R, WHILE, and REPEAT.
  - A CALL statement to invoke procedures and a RETURN statement.
  - Condition handling.

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Triggers (1 of 4)

- An SQL (compound) statement executed automatically by DBMS as side effect of a modification to named table.
- Use of triggers include:
  - Validating i g complex integrity con ould be difficult/impossible.
  - Supporting alerts.
  - Maintaining audit information.
  - Supporting replication.

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Triggers (2 of 4)

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Triggers (3 of 4)

- BEFORE trigger fired before and AFTER trigger is fired after associated event occurs.
- Triggered action is SQL procedure statement, which can be executed in
  - For each ro fected by the event. This is called a row-level tr
  - Only once for entire event (FOR EACH STATEMENT), which is default. This is called a statement-level trigger.

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Triggers (4 of 4)

- As more than one trigger can be defined on a table, order of firing is important. The following order is observed:

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(1) Execution of any BEFORE triggers on table.

(2) For each row nt:

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- Execute any BEFORE row er.

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- Execute the statement itse
- Apply any referential constraints.
- Execute any AFTER row-level trigger.

(3) Execute any AFTER trigger on table.

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Example 9.15 Use of AFTER Trigger

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Example 9.16 Use of AFTER Trigger with Condition

```
CREATE TRIGGER UpdateMailshotTable
    AFTER UPDATE OF rent ON PropertyForRent
    REFERENCING NEW ROW AS pfr
    FOR EACH RO
    BEGIN ATOMI
        DELETE FROM Mailshot                Rent > pfr.rent;
        UPDATE Mailshot SET rent = pfr.rent
        WHERE propertyNo = pfr.propertyNo;
    END;
```

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Triggers - Advantages and Disadvantages

- Major advantage - standard functions can be stored within database and enforced consistently.
- This can dramatically reduce complexity of applications.

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- However, there https://eduassistpro.github.io/ ages:
  - Complexity.
  - Hidden functionality.
  - Performance overhead.

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Large Objects

- A table field that holds large amount of data.
- Three different types:
  - Binary Large Object (BLOB).
  - Character L al CLOB.
- SQL:2011 LOB slightly differe inal type of BLOB that appears in many current ere BLOB is non-interpreted byte stream.
- In SQL:2011, LOB does allow some operations to be carried out in DBMS server.

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Example 9.17 Use of CLOB and BLOB

- Extend Staff table to hold a resume and picture for the staff member.

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Object-Oriented Extensions in Oracle (1 of 3)

- Many of the object-oriented features that appear in new SQL:2011 standard appear in Oracle in one form or another.

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- Oracle support types:

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  – object types
  – collection types.

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Object Types in Oracle (1 of 2)

- An object type is a schema object that has a name, a set of attributes based on the Oracle built-in data types or possibly other object types, and a set of methods.

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Object-Oriented Extensions in Oracle (2 of 3)

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Object-Oriented Extensions in Oracle (3 of 3)

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Object Types in Oracle (2 of 2)

- Pragma clause is a compiler directive that denies member functions read/write access to database tables and/or package variables.

- Can now creat :

```
CREATE TABLE Branch OF e
    (branchNo PRIMARY KEY);
```

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Methods in Oracle (1 of 3)

- Methods of an object type are classified as member, static, and comparison.
- Member method is a function/procedure that always has implicit SELF par (whose type is containing object
  - Useful as observer and muta

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- Static method is a function/procedure that does not have an implicit SELF parameter.
  - Useful for specifying user-defined constructors or cast methods and may be invoked by qualifying method with the type name, as in typename.method().

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Methods in Oracle (2 of 3)

- Comparison method used for comparing instances of objects.
- Oracle provides two ways to define an order relationship among objects

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  – a map meth to compare built-in types.
  – an order method uses its own internal logic to compare two objects of a given object type. It returns a value that encodes the order relationship. For example, may return −1 if first is smaller, 0 if they are equal, and 1 if first is larger.

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Methods in Oracle (3 of 3)

- Methods can be implemented in PL/SQL, Java, and ‘C’.
- Overloading is supported provided their formal parameters differ in number, order, or data type.

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Object Identifiers

- Every row object in an object table has associated logical OID, which uniquely identifies the row.
- The OID column is hidden from users and there is no access to its internal stru
- Oracle requires unique OID, which may be specified to come from t 's PK or to be system-generated.

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```
CREATE TABLE Branch OF BranchType
        (branch N o PRIMARYKEY)
OBJECT IDENTIFIER PRIMARYKEY;
```

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REF Data Type (1 of 2)

- Oracle provides a built-in data type called REF to encapsulate references to row objects of a specified object type.
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- In effect, a REF sociation between two row objects
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- A REF can be used to examin the object it refers to and to obtain a copy of the object it refers to.
- Only changes that can be made to a REF are to replace its contents with a reference to a different object of same object type or to assign it a null value.

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REF Data Type (2 of 2)

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Collection Types

- Oracle supports two collection types: **array types** and **table types**.

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- An array is an ordered set of data elements, all of same data type.

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- Each element has an **index**, a rresponding to the element's position in the a

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- An array can have a fixed or variable size, although in latter case maximum size must be specified when array type is declared.

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Nested Tables (1 of 3)

- An unordered set of data elements, all of same data type.
- It has a single column of a built-in type or an object type.

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- If column is an so be viewed as a multi-column ta

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ch attribute of the object type.

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Nested Tables (2 of 3)

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- Can now modify StaffType to include this new type:

  nextOfKin NextOfKinNestedType

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Nested Tables (3 of 3)

- Can now create Staff table:

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Manipulating Object Tables (1 of 2)

```
INSERT INTO Staff VALUES (‘SG37’, ‘Ann’,
  ‘Beech’, ‘Assistant’, ‘F’, ‘10-Nov-1960’, 12000,
     NextOfKinNestedType());

INSERT INTO                          OfKin
                      FRO
                      WH                  No = ‘SG5’)
  VALUES (‘John’, ‘Brand’, ‘0141-848-2000’);
```

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Manipulating Object Tables (2 of 2)

- Can now insert object into Branch table:

```
INSERT INTO Branch
        SELECT '                              Main St',
               'Gl                             s),
               TelNoArrayType('0                78',
                                                9-4439')
        FROM Staff s
        WHERE s.staffNo = 'SG5';
```

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Querying Object Tables

```
SELECT b.branchNo
FROM Branch b
ORDER BY VALUE(b);
```

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```
SELECT b.br
        DEREF(b.manager),          st
FROM Branch b
WHERE b.address.city = 'Glasgow'
ORDER BY VALUE(b);
```

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Object Views

- **Object view** is a virtual object table.
- In Oracle, can create an object view that not only restricts access to some data but also prevents some methods from being invo ethod.

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- Also argued that object views imple migration path from a purely relational-b ation to an object-oriented one, thereby allowing companies to experiment with this new technology.

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Database Systems: A Practical Approach to Design, Implementation, and Management

Sixth Edition

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Chapter 27

t-Oriented DBMSs –
pts and Design

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Learning Objectives (1 of 2)

27.1 The next generation of database systems.

27.2 Framework for an OO data model.

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27.3 Basics of th

27.4 Basics of pe https://eduassistpro.github.io/ nguages.

27.5 Main strategies for develop Add WeChat edu_assist_pro DBMS.

27.6 Single-level v. two-level storage models.

27.7 Pointer swizzling.

27.8 How an OODBMS accesses records.

27.8 Persistent schemes.

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Learning Objectives (2 of 2)

27.9 Advantages and disadvantages of orthogonal persistence.

27.9 Issues underlying OODBMSs.

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27.10 Advantage https://eduassistpro.github.io/ OODBMSs.

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Next Generation Database Systems

- **First Generation DBMS:** Network and Hierarchical
  - Required complex programs for even simple queries.
  - Minimal data independence.
  - No widely a dation.
- **Second Generation DBMS:** BMS
  - Helped overcome these pr
- **Third Generation DBMS:** OODBMS and ORDBMS.

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History of Data Models

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Object-Oriented Data Model (1 of 3)

No one agreed object data model. One definition:

- Object-Oriented Data Model (OODM)
  - Data model that captures semantics of objects supported i mming.

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- Object-Oriented Database (O
  - Persistent and sharable co bjects defined by an ODM.
- Object-Oriented DBMS (OODBMS)
  - Manager of an ODB.

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Object-Oriented Data Model (2 of 3)

- Zdonik and Maier present a threshold model that an OODBMS must, at a minimum, satisfy:
  - It must provide database functionality.
  - It must sup
  - It must prov
  - It must support objects wit state.

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Object-Oriented Data Model (3 of 3)

- Khoshafian and Abnous define OODBMS as:
  - OO = ADTs + Inheritance + Object identity
  - OODBMS = OO + Database capabilities.

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- Parsaye **et al.**

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  - High-level query language optimization.

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  - Support for persistence, at ctions: concurrency and recovery control.
  - Support for complex object storage, indexes, and access methods.
  - OODBMS = OO system + (1), (2), and (3).

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Commercial OODBMSs

- GemStone/S from Gemstone Systems Inc.,
- Objectivity/DB from Objectivity Inc.,

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- ObjectStore fro [illegible] orp.,

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- Versant Object [illegible] stObjects from Versant Corp.

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Origins of the Object-Oriented Data Model

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Functional Data Model (FDM)

- Interesting because it shares certain ideas with object approach including object identity, inheritance, overloading, and navigational access.
- In FDM, any da viewed as process of evaluating a nction with zero, one, or more arguments.
- Resulting data model is conceptually simple but very expressive.
- In the FDM, the main modeling primitives are **entities** and **functional relationships**.

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FDM - Entities

- Decomposed into (abstract) entity types and printable entity types.
- Entity types correspond to classes of 'real world' objects and declared a ents that return type ENTITY.

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- For example:

  Staff() → ENTITY

  PropertyForRent() → ENTITY.

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FDM – Printable Entity Types and Attributes

- Printable entity types are analogous to base types in a programming language.
- Include: INTEGER, CHARACTER, STRING, REAL, and DATE.

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- An attribute is a [illegible] **p**, taking the entity type as an argument and retur[illegible]table entity type.

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- For example:

staffNo(Staff) → STRING

sex(Staff) → CHAR

salary(Staff) → REAL

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FDM – Composite Attributes

Name() → ENTITY

Name(Staff) → NAME

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fName(Name) →

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lName(Name) →

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FDM – Relationships (1 of 2)

- Functions with arguments also model relationships between entity types.
- Thus, FDM makes no distinction between attributes and relationships.
- Each relationship may have a lationship defined.
- For example:

Manages(Staff) → PropertyForRent

ManagedBy(PropertyForRent) → Staff INVERSE OF Manages

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FDM – Relationships (2 of 2)

- Can also model *:* relationships:
  - Views(Client) —» PropertyForRent
  -

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- and attributes on relationships
  - viewDate(Client, Property — DATE

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FDM – Inheritance and Path Expressions

- Inheritance supported through entity types.
- Principle of substitutability also supported.

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- Derived functions can be defined from composition of multiple functions (note overloading):

  fName(Staff) → fName(Name(Staff))

  fName(Supervisor) → fName(IS-A-STAFF(Supervisor))

- Composition is a **path expression** (cf. dot notation):

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FDM – Declaration of FDM Schema

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FDM – Diagrammatic Representation of Schema

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FDM – Functional Query Languages

- Path expressions also used within a functional query.
- For example:

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RETRIEVE lName(Name(Viewed By(Manages(Staff))))
WHERE staffN

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- or in dot notation:

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RETRIEVE Staff.Manages.Vie me.lName
WHERE Staff.staffNo=‘SG14’

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FDM – Advantages

- Support for some object-oriented concepts.
- Support for referential integrity.
- Irreducibility.
- Easy extensibili
- Suitability for schema integrati
- Declarative query language.

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Persistent Programming Languages (PPLs) (1 of 3)

- Language that provides users with ability to (transparently) preserve data across successive executions of a program, and even allows such data to be used by ma

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- In contrast, dat guage (e.g. SQL) differs by its incorporation of f ond persistence, such as transacti ment, concurrency control, and recovery.

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Persistent Programming Languages (PPLs) (2 of 3)

- PPLs eliminate impedance mismatch by extending programming language with database capabilities.
  - In PPL, language's type system provides data model, containing ri ms.
- In some PPLs s' objects and are treated like any other object in
  - Procedures are assignable, may be result of expressions, other procedures or blocks, and may be elements of constructor types.
  - Procedures can be used to implement ADTs.

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Persistent Programming Languages (PPLs) (3 of 3)

- PPL also maintains same data representation in memory as in persistent store.
  - Overcomes difficulty and overhead of mapping between th

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- Addition of (tra to a PPL is important enhancement to ID ration of two paradigms provides more functionality and semantics.

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Alternative Strategies for Developing an OODBMS (1 of 2)

- Extend existing OO programming language.
  - GemStone extended Smalltalk.

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- Provide extensible OODBMS library.
  - Approach ta … and ObjectStore.

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- Embed OODB language cons … onventional host language.
  - Approach taken by O_2, which has extensions for C.

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Alternative Strategies for Developing an OODBMS (2 of 2)

- Extend existing database language with object-oriented capabilities.
  - Approach being pursued by RDBMS and OODBMS vendors.
  - Ontos and n of OSQL.
- Develop a novel database dat guage.

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Single-Level v. Two-Level Storage Model (1 of 3)

- Traditional programming languages lack built-in support for many database features.
- Increasing number of applications now require functionality fro … s and programming la…
- Such applications need to stor … ve large amounts of shared, structured data.

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Single-Level v. Two-Level Storage Model (2 of 3)

- With a traditional DBMS, programmer has to:
  - Decide when to read and update objects.
  - Write code to translate between application's object model and t MS.
  - Perform ad hen object is back from database, to gu ect will conform to its original type.

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Single-Level v. Two-Level Storage Model (3 of 3)

- Difficulties occur because conventional DBMSs have two-level storage model: storage model in memory, and database storage model on disk.

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- In contrast, OO ingle-level storage model, with sim th memory and in database stored on disk.

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  - Requires clever management of representation of objects in memory and on disk (called "pointer swizzling").

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Two-Level Storage Model for RDBMS

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Single-Level Storage Model for OODBMS

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Pointer Swizzling Techniques (1 of 2)

The action of converting object identifiers (OIDs) to main memory pointers.

- Aim is to optimize access to objects.
- Should be able d objects on secondary storage using their
- Once objects have been read want to record that objects are now in memory to prevent them from being retrieved again.

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Pointer Swizzling Techniques (2 of 2)

- Could hold lookup table that maps OIDs to memory pointers (e.g. using hashing).
- Pointer swizzling attempts to provide a more efficient strategy by stor [illegible] the place of referenced OID [illegible] the object is written back to disk.

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No Swizzling

- Easiest implementation is not to do any swizzling.
- Objects faulted into memory, and handle passed to application containing object's OID.

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- OID is used ev [illegible] cessed.

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- System must maintain some t [illegible] p table - Resident Object Table (ROT) [illegible] ject's virtual memory pointer can be located and then used to access object.

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- Inefficient if same objects are accessed repeatedly.
- Acceptable if objects only accessed once.

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Resident Object Table (ROT)

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Object Referencing (1 of 2)

- Need to distinguish between resident and non-resident objects.

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- Most techniques variations of edge marking or node marking.

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- Edge marking marks every ob with a tag bit:

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  - if bit set, reference is to m ter;
  - else, still pointing to OID and needs to be swizzled when object it refers to is faulted into.

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Object Referencing (2 of 2)

- Node marking requires that all object references are immediately converted to virtual memory pointers when object is faulted into memory.
- First approach i ique but second can be implem hardware-based techniques.

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Hardware-Based Schemes

- Use virtual memory access protection violations to detect accesses of non-resident objects.
- Use standard virtual memory hardware to trigger transfer of persistent da
- Once page has been faulted i re accessed via normal virtual memory pointer rther object residency checking is required.
- Avoids overhead of residency checks incurred by software approaches.

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Pointer Swizzling - Other Issues

- Three other issues that affect swizzling techniques:
  - Copy versus In-Place Swizzling.
  - Eager versus Lazy Swizzling.
  - Direct versu

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Copy Versus In-Place Swizzling

- When faulting objects in, data can either be copied into application's local object cache or accessed in-place within object manager's database cache.
- Copy swizzling ... s, in the worst case, only modi ... swizzled back to their OIDs.
- In-place may have to unswizzle entire page of objects if one object on page is modified.

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Eager Versus Lazy Swizzling

- Moss defines eager swizzling as swizzling all OIDs for persistent objects on all data pages used by application, before any object can be accessed.
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- More relaxed d g to all persistent OIDs within obj s to access.
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- Lazy swizzling only swizzles p hey are accessed or discovered.

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Direct versus Indirect Swizzling

- Only an issue when swizzled pointer can refer to object that is no longer in virtual memory.
- With direct swizzling, virtual memory pointer of referenced obje wizzled pointer.
- With indirect swizzling, virtual inter is placed in an intermediate object, which laceholder for the actual object.
  – Allows objects to be uncached without requiring swizzled pointers to be unswizzled.

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Accessing an Object with a RDBMS

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Accessing an Object with an ODBMS

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Persistent Schemes

- Consider three persistent schemes:
  - Checkpointing.
  - Serialization.
  - Explicit Pag
- Note, persistence can also be (object) code and to the program execution

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Checkpointing

- Copy all or part of program's address space to secondary storage.
- If complete address space saved, program can restart from checkpoin
- In other cases, only program's d.
- Two main drawbacks:
  - Can only be used by program that created it.
  - May contain large amount of data that is of no use in subsequent executions.

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Serialization (1 of 2)

- Copy closure of a data structure to disk.
- Write on a data value may involve traversal of graph of objects reachable from the value, and writing of flattened version of struc
- Reading back flattened data s duces new copy of original data structure.
- Sometimes called serialization, pickling, or in a distributed computing context, marshaling.

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Serialization (2 of 2)

- Two inherent problems:
  - Does not preserve object identity.
  - Not incremental, so saving small changes to a large data structu

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Explicit Paging

- Explicitly ‘page’ objects between application heap and persistent store.
- Usually requires conversion of object pointers from disk-based scheme e.

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- Two common methods for cre ing persistent objects:
  - Reachability-based.
  - Allocation-based.

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Explicit Paging - Reachability-Based Persistence

- Object will persist if it is reachable from a persistent root object.
- Programmer does not need to decide at object creation time whether o nt.
- Object can become persistent it to the reachability tree.
- Maps well onto language that contains garbage collection mechanism (e.g. Smalltalk or Java).

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Explicit Paging - Allocation-Based Persistence (1 of 2)

- Object only made persistent if it is explicitly declared as such within the application program.
- Can be achieved in several ways:
  - By class.
  - By explicit call.

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Explicit Paging - Allocation-Based Persistence (2 of 2)

- By class
  - Class is statically declared to be persistent and all instances made persistent when they are created.
  - Class may [illegible] upplied persistent class.
- By explicit call
  - Object may be specified as persistent when it is created or dynamically at runtime.

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Orthogonal Persistence

- Three fundamental principles:
  - Persistence independence.
  - Data type orthogonality.
  - Transitive p erred to as 'persistence term 'transitive persistence' used here).

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Persistence Independence

- Persistence of object independent of how program manipulates that object.
- Conversely, code fragment independent of persistence of data it manipul
- Should be possible to call fun parameters sometimes objects with long t ence and sometimes only transient.
- Programmer does not need to control movement of data between long-term and short-term storage.

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Data Type Orthogonality

- All data objects should be allowed full range of persistence irrespective of their type.
- No special cases where object is not allowed to be long-lived or is not al
- In some PPLs, persistence is butable to only subset of language data types

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Transitive Persistence

- Choice of how to identify and provide persistent objects at language level is independent of the choice of data types in the language.
- Technique that dentification is reachability-ba

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Orthogonal Persistence - Advantages

- Improved programmer productivity from simpler semantics.
- Improved maintenance.
- Consistent prot r whole environment.
- Support for incremental evolut
- Automatic referential integrity.

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Orthogonal Persistence - Disadvantages

- Some runtime expense in a system where every pointer reference might be addressing persistent object.
  - System required to test if object must be loaded in from disk-re
- Although ortho tes transparency, system with support for sharin ncurrent processes cannot be fully transparent.

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Versions

Allows changes to properties of objects to be managed so that object references always point to correct object version.

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- Itasca identifies
  - Transient V
  - Working Versions.
  - Released Versions.

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Versions and Configurations (1 of 2)

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Versions and Configurations (2 of 2)

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Schema Evolution (1 of 2)

- Some applications require considerable flexibility in dynamically defining and modifying database schema.
- Typical schema changes:

(1) Changes to cl

(a) Modifying Attributes.

(b) Modifying Methods.

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Schema Evolution (2 of 2)

(2) Changes to inheritance hierarchy:

- (a) Making a class S superclass of a class C.
- (b) Removing S from list of superclasses of C.
- (c) Modifyin of C.

(3) Changes to s eating and deleting classes and modifying class na

- Changes must not leave schema inconsistent.

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Schema Consistency (1 of 4)

1. Resolution of conflicts caused by multiple inheritance and redefinition of attributes and methods in a subclass.

1.1 Rule of precedence of subclasses over superclasses.

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1.2 Rule of prece sses of a different origin.

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1.3 Rule of precedence betwee ses of the same origin.

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Schema Consistency (2 of 4)

2. Propagation of modifications to subclasses.

2.1 Rule for propagation of modifications.

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2.2 Rule for prop in the event of conflicts.

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2.3 Rule for modification of dom

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Schema Consistency (3 of 4)

3. Aggregation and deletion of inheritance relationships between classes and creation and removal of classes.

3.1 Rule for inserting superclasses.

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3.2 Rule for remo

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3.3 Rule for inserting a class int

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3.4 Rule for removing a class from a schema.

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Schema Consistency (4 of 4)

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Client-Server Architecture (1 of 2)

- Three basic architectures:
  - Object Server.
  - Page Server.
  - Database S

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Object Server

- Distribute processing between the two components.
- Typically, client is responsible for transaction management and interfacing to programming language.
- Server respons ctions.
- Best for cooperative, object-to cessing in an open, distributed environment

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Page and Database Server

Page Server

- Most database processing is performed by client.

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- Server respons ge and providing pages at client’

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Database Server

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- Most database processing performed by server.
- Client simply passes requests to server, receives results and passes them to application.
- Approach taken by many RDBMSs.

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Client-Server Architecture (2 of 2)

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Architecture - Storing and Executing Methods (1 of 2)

- Two approaches:
  - Store methods in external files.
  - Store methods in database.

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- Benefits of latte

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  - Eliminates redundant cod

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  - Simplifies modifications.
  - Methods are more secure.
  - Methods can be shared concurrently.
  - Improved integrity.
- Obviously, more difficult to implement.

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Architecture - Storing and Executing Methods (2 of 2)

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Benchmarking - Wisconsin Benchmark (1 of 2)

- Developed to allow comparison of particular DBMS features.
- Consists of set of tests as a single user covering:
  - updates/del on-key attributes;
  - projections involving differ of duplication in the attributes and select ifferent selectivities on indexed, non-index, and clustered attributes;
  - joins with different selectivities;
  - aggregate functions.

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Benchmarking - Wisconsin Benchmark (2 of 2)

- Original benchmark had 3 relations: one called Onektup with 1000 tuples, and two others called Tenktup1/Tenktup2 with 10000 tuples.

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- Generally usefu r for highly skewed attribute distrib sed are relatively simplistic.

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- Consortium of manufacturers formed Transaction Processing Council (TPC) in 1988 to create series of transaction-based test suites to measure database/TP environments.

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TPC Benchmarks

- TPC-A and TPC-B for OLTP (now obsolete).
- TPC-C replaced TPC-A/B and based on order entry application.
- TPC-H for **ad h** vironments.
- TPC-R for business reporting sion support environments.
- TPC-W, a transactional Web benchmark for eCommerce.

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Object Operations Version 1 (OO1) Benchmark

- Intended as generic measure of OODBMS performance. Designed to reproduce operations common in advanced engineering applications, such as finding all parts connected to a nnected to one of those parts, an ven levels.

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- About 1990, benchmark was r Stone, Ontos, ObjectStore, Objectivity/DB, a , and INGRES and Sybase. Results showed an average 30-fold performance improvement for OODBMSs over RDBMSs.

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OO7 Benchmark

- More comprehensive set of tests and a more complex database based on parts hierarchy.
- Designed for detailed comparisons of OODBMS products.

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- Simulates CAD/CAM environ sts system performance in area of object- avigation over cached data, disk-resident data, and both sparse and dense traversals.
- Also tests indexed and nonindexed updates of objects, repeated updates, and the creation and deletion of objects.

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Advantages of OODBMSs

- Enriched Modeling Capabilities.
- Extensibility.
- Removal of Imp
- More Expressiv
- Support for Schema Evolution
- Support for Long Duration Transactions.
- Applicability to Advanced Database Applications.
- Improved Performance.

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Disadvantages of OODBMSs

- Lack of Universal Data Model.
- Lack of Experience.

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- Lack of Standar

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- Query Optimiza psulation.

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- Object Level Locking may imp ance.
- Complexity.
- Lack of Support for Views.
- Lack of Support for Security.

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Comparison of ORDBMS and OODBMS – Data Modeling

Feature	ORDBMS	OODBMS
Object identity (OID)	Supported through REF type	Supported
Encapsulation	Supported through UDTs	Supported but broken for queries
Inheritance	[illegible] hierarchies for U[illegible] tables)	Supported
Polymorphism	Supported (UDF invocation based on the generic function)	Supported as in an object oriented programming model language
Complex objects	Supported through UDTs	Supported
Relationships	Strong support with user-defined referential integrity constraints	Supported (for example, using class libraries)

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Comparison of ORDBMS and OODBMS – Data Access

Feature	ORDBMS	OODBMS
Creating and accessing persistent data	Supported but not transparent	Supported but degree of transparency differs between products
Ad hoc query facility	[illegible]	[illegible]upported through ODMG [illegible]0
Navigation	Supported by R[illegible]	[illegible]ng support
Integrity constraints	Strong support	No support
Object server/page server	Object server	Either
Schema evolution	Limited support	Supported but degree of support differs between products

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Comparison of ORDBMS and OODBMS – Data Sharing

Feature	ORDBMS	OODBMS
ACID transactions	Strong support	Supported
Recovery	Strong support	Supported but degree of support differs between products
Advanced transaction		pported but degree of pport differs between oducts
Security, integrity, and views	Strong support	Limited support

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OO Database Design – OODB vs. CDM

OODM	CDM	Difference
Object	Entity	Object includes behavior
Attribute	Attribute	None
Association	Re[illegible]	[illegible]s are the same but [illegible] in OODM includes both [illegible]vior
Message		[illegible]ing concept in CDM
Class	Entity type/Supertype	None
Instance	Entity	None
Encapsulation		No corresponding concept in CDM

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Relationships

- Relationships represented using reference attributes, typically implemented using OIDs.
- Consider how to represent following binary relationships according to th
  - 1:1
  - 1:*
  - *:*

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1:1 Relationship Between Objects A and B

- Add reference attribute to A and, to maintain referential integrity, reference attribute to B.

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1 : * Relationship Between Objects A and B

- Add reference attribute to B and attribute containing set of references to A.

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$*:*$ Relationship Between Objects A and B

- Add attribute containing set of references to each object.
- For relational database design, would decompose $*:N$ into two $1:*$ rel rmediate entity. Can also repres BMS.

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* : * Relationships

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Alternative Design for * : * Relationships

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Referential Integrity (1 of 2)

Several techniques to handle referential integrity:

- Do not allow user to explicitly delete objects.

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  – System is responsible for “garbage collection”.

- Allow user to d https://eduassistpro.github.io/ are no longer required.

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  – System may detect invalid automatically and set reference to NULL or disallow the deletion.

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Referential Integrity (2 of 2)

- Allow user to modify and delete objects and relationships when they are no longer required.
  - System automatically maintains the integrity of objects.
  - Inverse attri aintain referential integrity.

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Behavioral Design

- EER approach must be supported with technique that identifies behavior of each class.
- Involves identifying:
  - public meth
  - private methods: internal t
- Three types of methods:
  - constructors and destructors
  - access
  - transform.

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Behavioral Design - Methods

- Constructor - creates new instance of class.
- Destructor - deletes class instance no longer required.

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- Access - return ttributes (Get).

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- Transform - ch ance (Put).

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Identifying Methods

- Several methodologies for identifying methods, typically combine following approaches:
  - Identify classes and determine methods that may be usefully pro
  - Decompose fashion and determine methods requir e required functionality.

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UML (1 of 2)

- Represents unification and evolution of several OOAD methods, particularly:
  - Booch method,
  - Object Mod
  - Object-Orie ing (OOSE).
- Adopted as a standard by OM pted by software community as primary notation for modeling objects and components.

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UML (2 of 2)

- Defined as **"a standard language for specifying, constructing, visualizing, and documenting the artifacts of a software system".**

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- The UML does ular methodology, but instead is fl to fit any approach and can be used in with a wide range of software lifecycles an ent processes.

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UML – Design Goals

- Provide ready-to-use, expressive visual modeling language so users can develop and exchange meaningful models.
- Provide extensibility and specialization mechanisms to extend core concepts.
- Be independent of uages and development processes.
- Provide a formal basis for understan eling language.
- Encourage growth of object-oriented tools market.
- Support higher-level development concepts such as collaborations, frameworks, patterns, and components.
- Integrate best practices.

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UML – Diagrams (1 of 2)

- Structural:
  - class diagrams
  - object diagrams
  - component d
  - deployment
- Behavioral:
  - use case diagrams
  - sequence diagrams
  - collaboration diagrams
  - statechart diagrams
  - activity diagrams.

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UML – Diagrams (2 of 2)

- Model instances of classes and used to describe system at a particular point
- Can be used to class diagram with "real world" data and record test cases.

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UML – Component Diagrams

- Describe organization and dependencies among physical software components, such as source code, run-time (binary) code, and executables.

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UML – Deployment Diagrams

- Depict configuration of run-time system, showing hardware nodes, components that run on these nodes, and connections between nodes.

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UML – Use Case Diagrams

- Model functionality provided by system (**use cases**), users who interact with system (**actors**), and association between users and the functionality.

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- Used in require alysis phase to represent high-l stem.

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- More specifically, specifies a s f actions, including variants, that system can perform and that yields an observable result of value to a particular actor.

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UML – Use Case Diagrams (1 of 2)

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UML – Use Case Diagrams (2 of 2)

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UML – Sequence Diagrams (1 of 2)

- Model interactions between objects over time, capturing behavior of an individual use case.
- Show the objects and the **messages** that are passed between these

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UML – Sequence Diagrams (2 of 2)

Figure 25.18 Sequence diagram for search properties use case.

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UML – Collaboration Diagrams (1 of 2)

- Show interactions between objects as a series of sequenced messages.
- Cross between an object diagram and a sequence diagram.
- Unlike sequence diagram, whi mn/row format, collaboration diagram uses fre ngement, which makes it easier to see all interactions involving a particular object.

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UML – Collaboration Diagrams (2 of 2)

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UML – Statechart Diagrams

- Show how objects can change in response to external events.
- Usually model transitions of a specific object.

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UML – Activity Diagrams (1 of 2)

- Model flow of control from one activity to another.
- Typically represent invocation of an operation, a step in a business process, or an entire business process.
- Consist of activi[illegible] between them.

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UML – Activity Diagrams (2 of 2)

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UML – Usage in Database Design Methodology (1 of 2)

- Produce use case diagrams from requirements specification or while producing requirements specification to depict main functions required of system. Can be augme riptions.

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- Produce first cu del).

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- Produce a sequence diagram e case or group of related use cases.
- May be useful to add a **control class** to class diagram to represent interface between the actors and the system.

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UML – Usage in Database Design Methodology (2 of 2)

- Update class diagram to show required methods in each class.
- Create state diagram for each class to show how class changes state i s. Messages are identified from
- Revise earlier diagrams base owledge gained during this process.

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