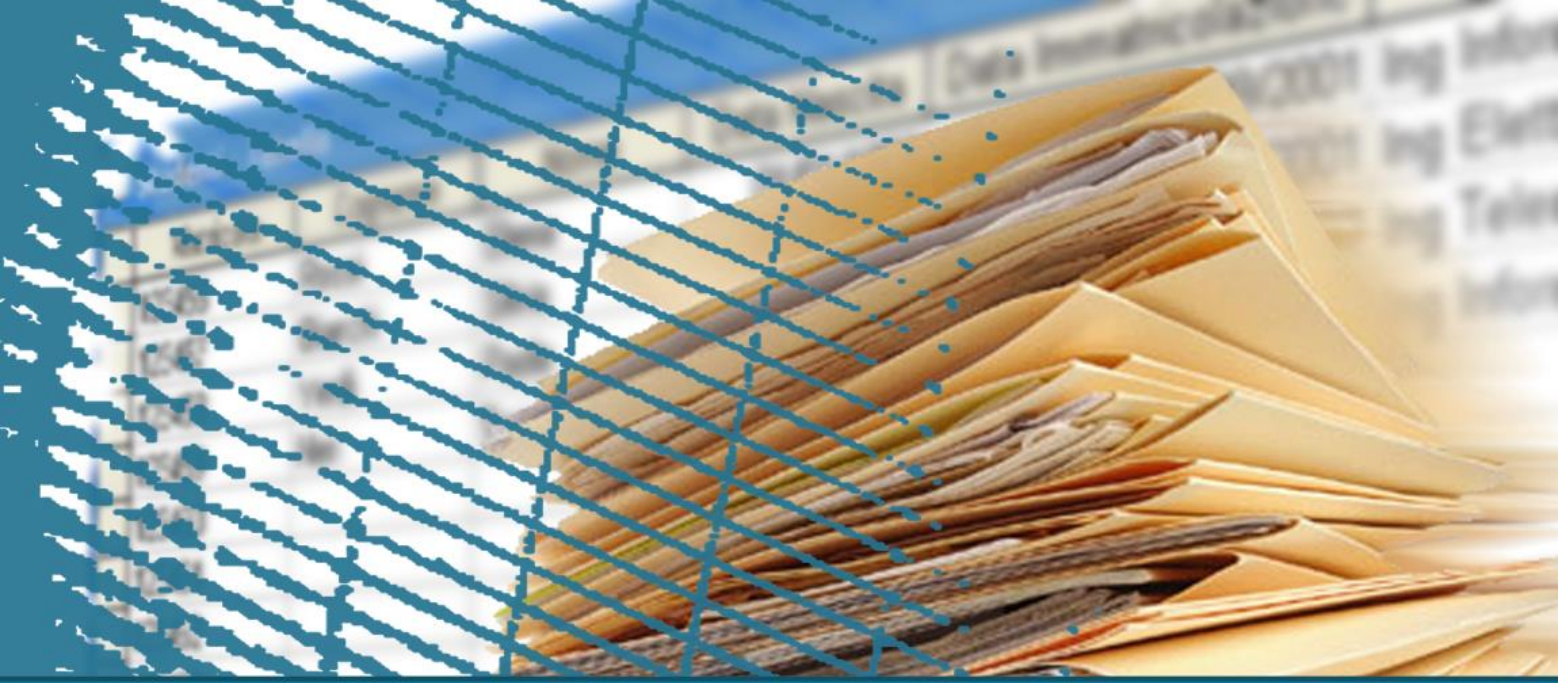
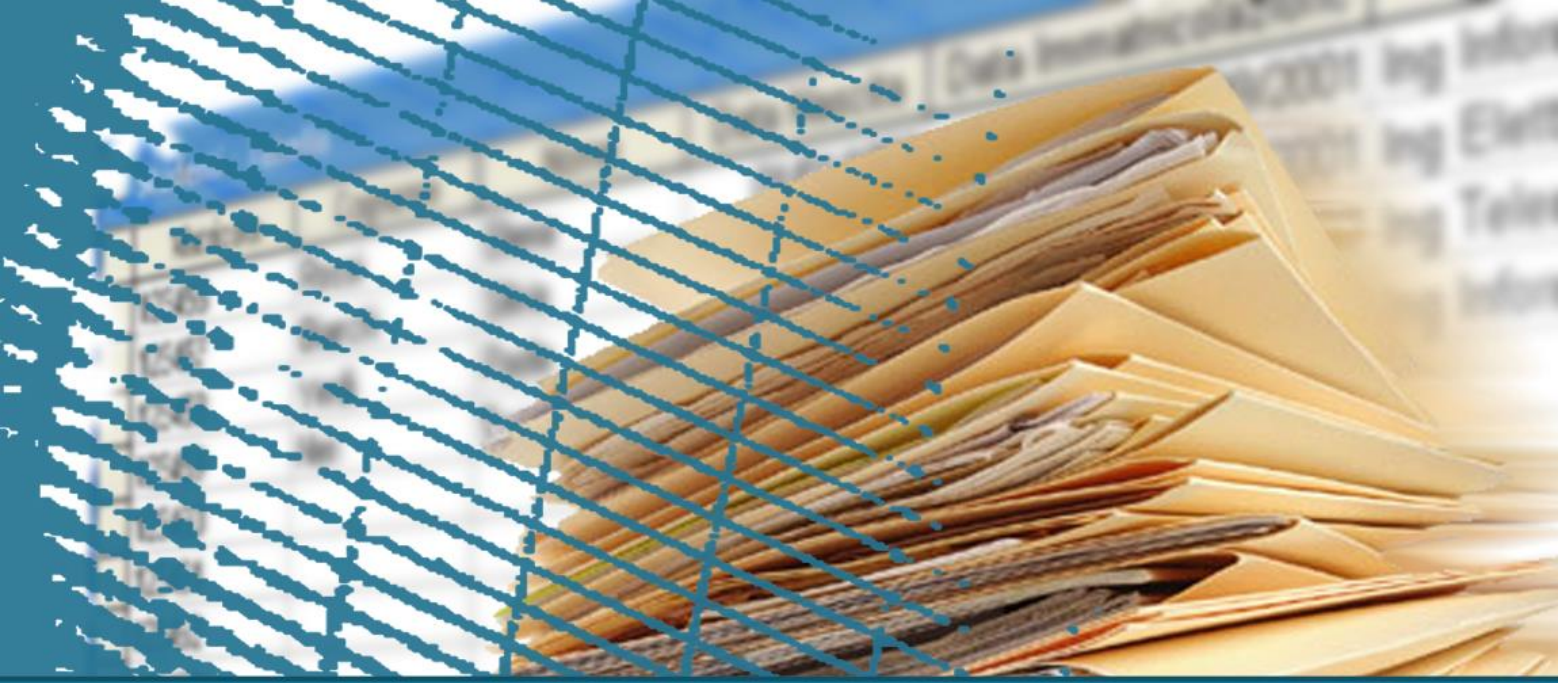


SQL language: basics

Managing tables

Managing tables

- Creating a table
- Modifying table structure
- Deleting a table
- The data dictionary
- Data integrity



Managing tables

Creating a table

Creating a table (1/3)

- The following SQL DDL (Data Definition Language) command must be used

  CREATE TABLE

- It allows
  - defining all attributes (i.e., columns) in the table
  - defining integrity constraints on the table data

Creating a table (2/3)

CREATE TABLE *TableName*
(*AttributeName Domain* [*DefaultValue*]
[Constraints]
{ , *AttributeName Domain* [*DefaultValue*]
[*Constraints*]}
OtherConstraints
);

Creating a table (3/3)

- *Domain*
  - it defines the data type of the attribute
    - predefined domains of the SQL language (elementary domains)
    - user-defined domains (using the predefined domains)
- *Constraints*
  - it allows specifying integrity constraints for the attribute
- *OtherConstraints*
  - it allows specifying general integrity constraints on the table

Domain definition (1/2)

- *Default Value*
  - it allows specifying a default value for the attribute

DEFAULT

< *GenericValue* | USER | CURRENT_USER | SESSION_USER | SYSTEM_USER | NULL>

Domain definition (2/2)

- *GenericValue*
  - a value compatible with the attribute domain
- *USER
  - user identifier
- NULL
  - base default value

Elementary domains (1/6)

- Character: single characters or strings (possibly variable-length)

  CHARACTER [VARYING] [(*Length*)]
  [CHARACTER SET *CharacterFamilyName*]

  - VARCHAR for short

- Single bits (booleans) or bit strings

  BIT [VARYING] [(*Length*)]

Elementary domains (2/6)

- Exact numeric domains

  NUMERIC [(*Precision, Scale*)]
  DECIMAL [(*Precision, Scale*)]
  INTEGER
  SMALLINT

- NUMERIC and DECIMAL are base-ten numbers

Elementary domains (3/6)

NUMERIC [(*Precision, Scale*)]

DECIMAL [(*Precision, Scale*)]

- Precision
  - total number of digits
  - for the NUMERIC domain, precision represents an exact requirement
  - for the DECIMAL domain, precision is a minimum requirement

Elementary domains (3/6)

NUMERIC [(*Precision, Scale*)]

DECIMAL [(*Precision, Scale*)]

- Scale
  - number of decimal places
- Example: for number 123.45
  - precision is 5, scale is 2

Elementary domains (4/6)

- Approximate numeric domains

  FLOAT [(*n*)]

  REAL

  DOUBLE PRECISION

- n specifies precision
  - it is the number of bits used to store the mantissa of a floating point number represented in scientific notation
  - it is a value ranging from 1 to 53
  - the default value is 53

Elementary domains (5/6)

INTERVAL *FirstUnitOfTime*
[TO *LastUnitOfTime*]

- Units of time are divided into two groups
  - year, month
  - day, hour, minute, second
- Example: INTERVAL year TO month
  - stores a period of time using the year and month fields
- Example: INTERVAL day TO second
  - stores a period of time using the day, hour, minute and second field

Elementary domains (6/6)

- TIMESTAMP [(*Precision*)] [WITH TIME ZONE]
  - it stores the values specifying the year, the month, the day, the hour, the minutes, the seconds and possibly the fraction of second
  - it uses 19 characters, plus the characters needed to represent the precision
  - notation
    - YYYY-MM-DD hh:mm:ss:p

Defining a domain (1/2)

- CREATE DOMAIN command
  - it defines a new domain that may be used in attribute definitions
- Syntax

  CREATE DOMAIN *DomainName* AS *DataType*
  [*DefaultValue*] [*Constraint*]
- *DataType* is an elementary domain

Defining a domain (2/2)

- Example

```
CREATE DOMAIN Grade AS SMALLINT
        DEFAULT NULL
    CHECK (Grade >= 18 and Grade <=30)
```

Definition of the supplier and product DB

- Creation of the supplier table

S

SId	SName	#Employees	City

```
CREATE TABLE S (SId          CHAR(5),
                SName        CHAR(20),
                #Employees   SMALLINT,
                City         CHAR(15));
```

- The definition of integrity constraints is missing

Definition of the supplier and product DB

- Creation of the product table

P

PId	PName	Color	Size	Store

```
CREATE TABLE P (PId      CHAR(6),
                PName    CHAR(20),
                Color    CHAR(6),
                Size     SMALLINT,
                Store    CHAR(15));
```

- The definition of integrity constraints is missing

Definition of the supplier and product DB

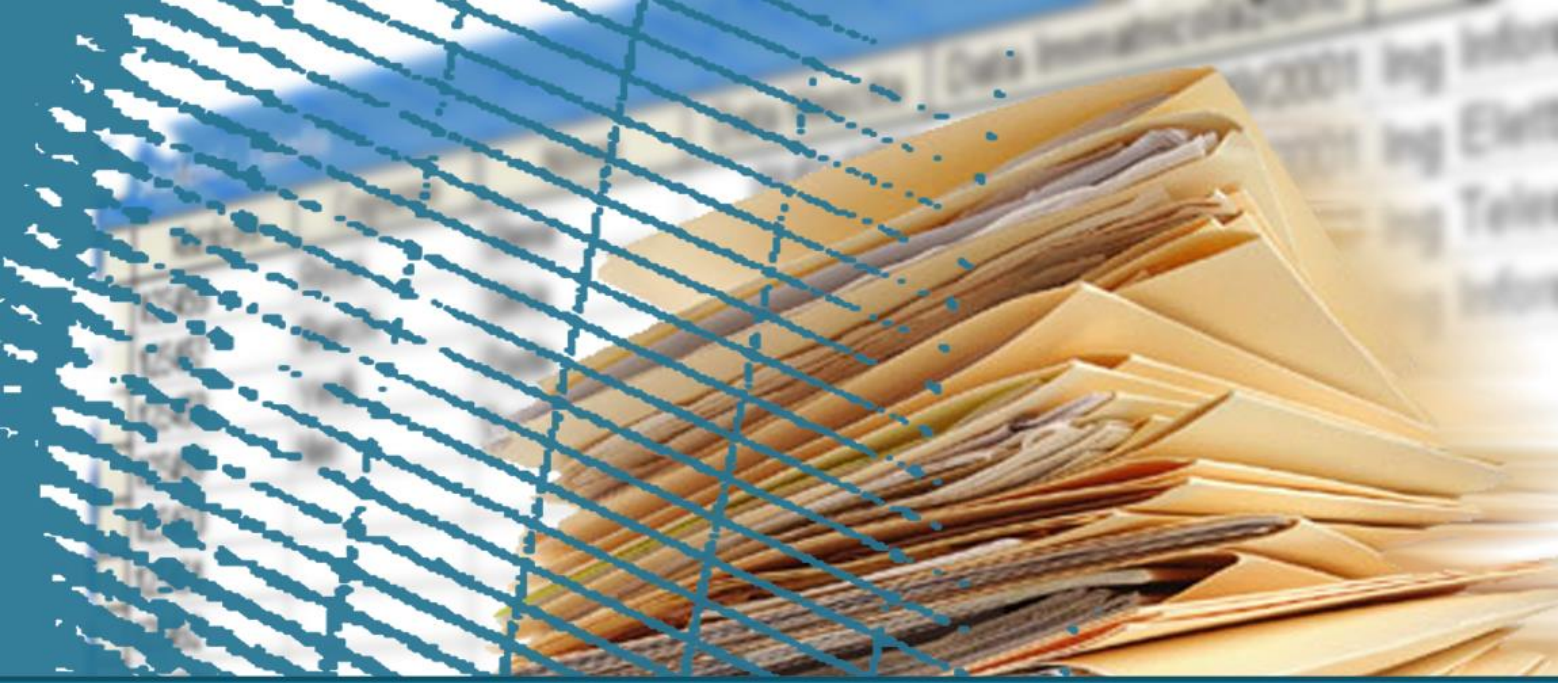
- Creation of the supplier-product table

SP

SId	PId	Qty

```
CREATE TABLE SP (SId    CHAR(5),
                 PId    CHAR(6),
                 Qty    INTEGER);
```

- The definition of integrity constraints is missing



Managing tables

Modifying table structure

The ALTER TABLE command (1/3)

- The following "alterations" are possible
  - adding a new column
  - defining a new default value for an existing column (attribute)
    - for example, replacing a previous default value
  - deleting an existing column (attribute)
  - defining a new integrity constraint
  - deleting an existing integrity constraint

The ALTER TABLE command (2/3)

ALTER TABLE *TableName*
< ADD COLUMN <Attribute-Definition> |
  ALTER COLUMN *AttributeName*
    < SET <Default-Value-Definition> | DROP DEFAULT>|
  DROP COLUMN AttributeName
    < CASCADE | RESTRICT > |
  ADD CONSTRAINT [ConstraintName]
    < unique-constraint-definition > |
    < referential-integrity-constraint-definition > |
    < check-constraint-definition > |
  DROP CONSTRAINT [ConstraintName]
    < CASCADE | RESTRICT >
>

The ALTER TABLE command (3/3)

- RESTRICT
  - the element (column or constraint) is not removed if it appears in the definition of some other element
  - default option
- CASCADE
  - all elements with a dependency on a deleted element will be removed, until there are no unresolved dependencies (i.e., there are no more elements whose definition references a deleted element)

The ALTER TABLE command: example no.1

- Add column #Members to the supplier table

S

SId	SName	#Employees	City	#Members

```
ALTER TABLE S
 ADD COLUMN #Members SMALLINT;
```

The ALTER TABLE command: example no.2

- Delete column #Employees from the supplier table

S

SId	SName	#Employees	City

```
ALTER TABLE S
 DROP COLUMN #Employees RESTRICT;
```

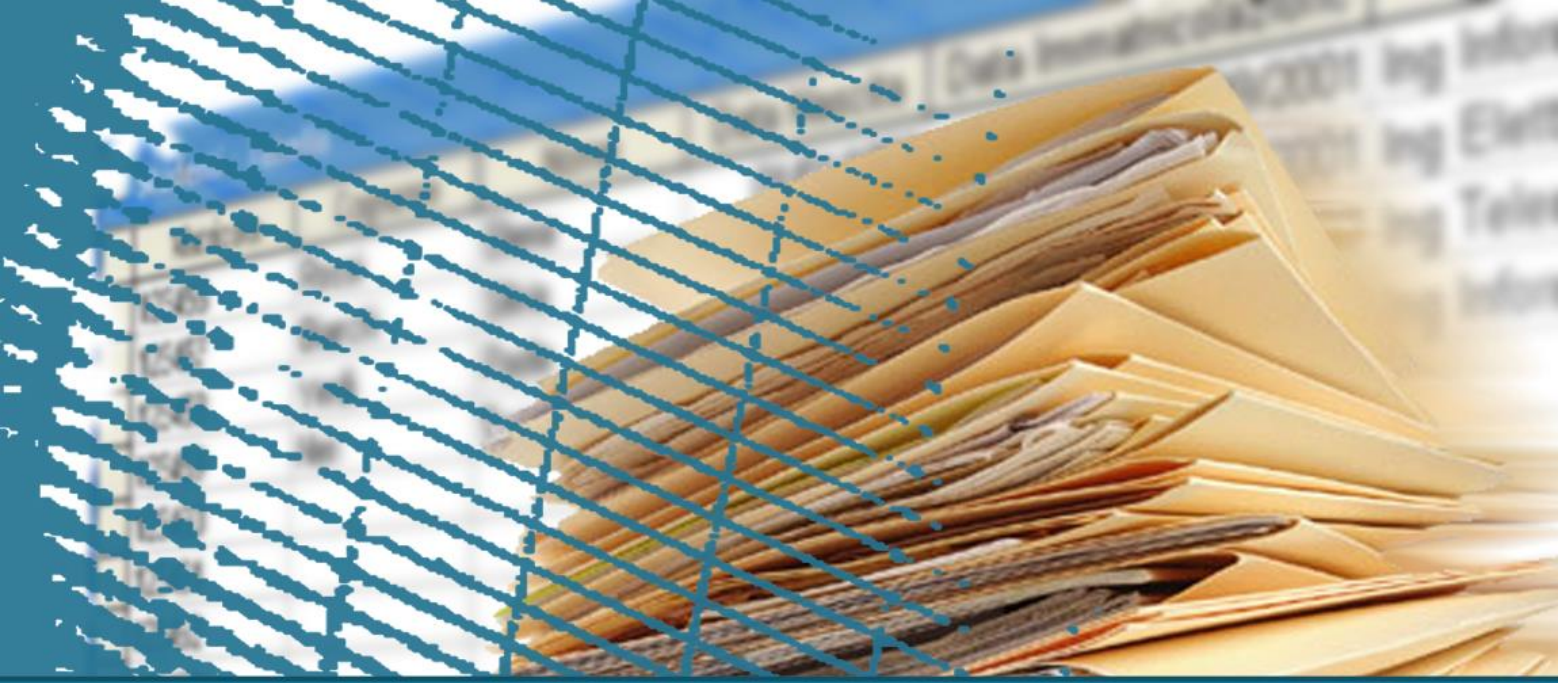
The ALTER TABLE command: example no.3

- Add a default value of 0 to column Quantity of the supplier-product table

SP

SId	PId	Qty

```
ALTER TABLE SP
 ALTER COLUMN Qty SET DEFAULT 0;
```



Managing tables

Deleting a table

Deleting a table

DROP TABLE *TableName*
[RESTRICT| CASCADE];

- All of the table rows are deleted along with the table
- RESTRICT
  - the table is not deleted if it appears in the definition of some table, constraint or view
  - default option
- CASCADE
  - if the table appears in the definition of some view, the latter is also deleted

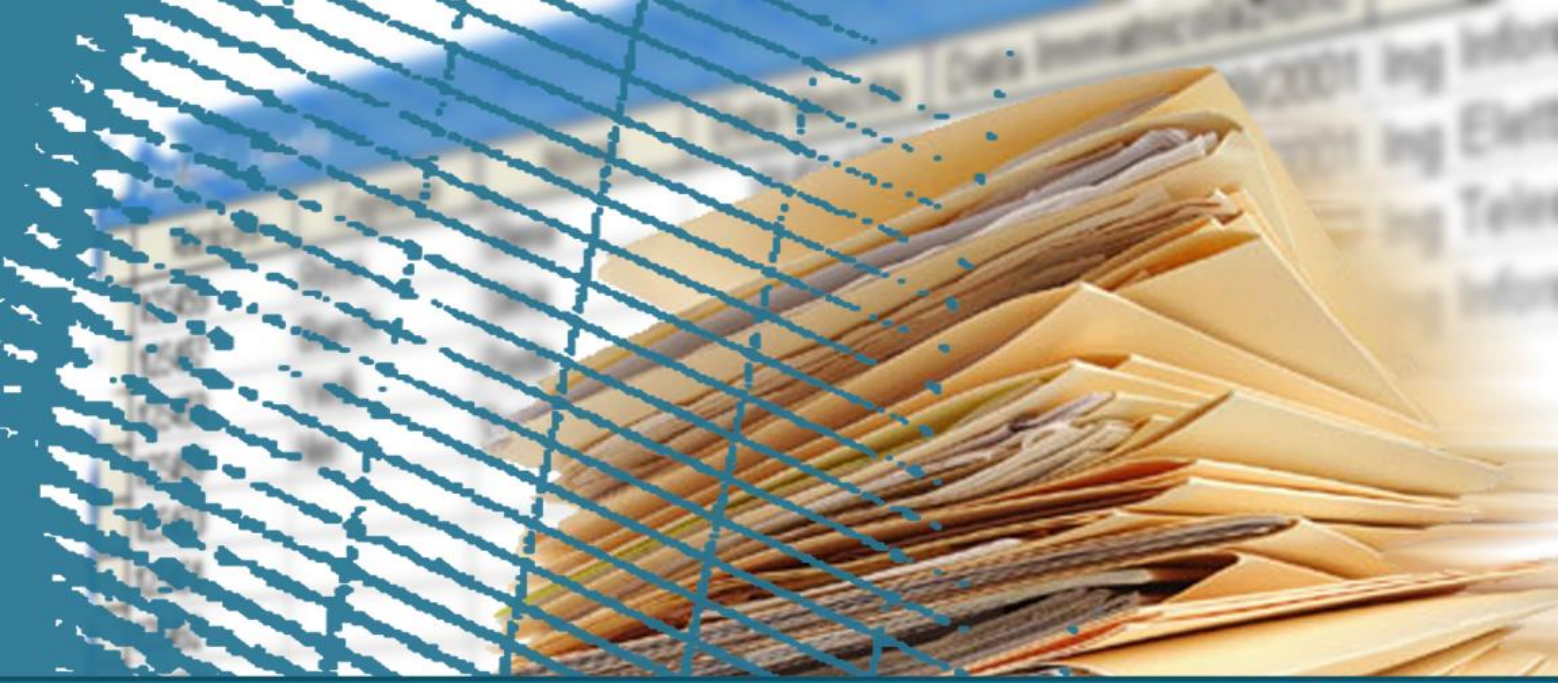
Deleting a table: example

- Delete the supplier table

S

SId	SName	#Employees	City

```
DROP TABLE S;
```



Managing tables

The data dictionary

The data dictionary (1/2)

- Metadata are information (data) about data
  - they may be stored in database tables
- The data dictionary contains the metadata of a relational database
  - it contains information about the database objects
  - it is managed directly by the relational DBMS
  - it may be queried by means of SQL commands

The data dictionary (2/2)

- It contains various pieces of information
  - descriptions of all database structures (tables, indices, views)
  - SQL stored procedures
  - user privileges
  - statistics
    - on the database tables
    - on the database indices
    - on the database views
    - on the evolution of the database

Information about tables

- For each database table, the data dictionary contains
  - table name and physical structure of the file storing the table
  - name and data type for each attribute
  - name of all indices created on the table
  - integrity constraints

Data dictionary tables

- Data dictionary information is stored in several tables
  - each DBMS uses different names for different tables
- The data dictionary may be queried by means of SQL commands

The Oracle data dictionary (1/2)

- In Oracle 3 collections of information are defined for the data dictionary
  - USER_*: metadata related to the current user's data
  - ALL_*: metadata related to all users' data
  - DBA_*: metadata about system tables

The Oracle data dictionary (2/2)

- USER_* contains different tables and views, including:
  - USER_TABLES contains metadata to the user tables
  - USER_TAB_STATISTICS contains statistics computed on the user tables
  - USER_TAB_COL_STATISTICS contains statistics computed on user table columns

Querying the data dictionary no.1

- Show the name of user-defined tables and the number of tuples stored in each table

```
SELECT Table_Name, Num_Rows
FROM USER_TABLES;
```

R

Table_Name	Num_Rows
S	5
P	6
SP	12

Querying the data dictionary no.2 (1/2)

- For each attribute in the supplier-product table, show the attribute name, the number of distinct values and the number of tuples with a NULL value

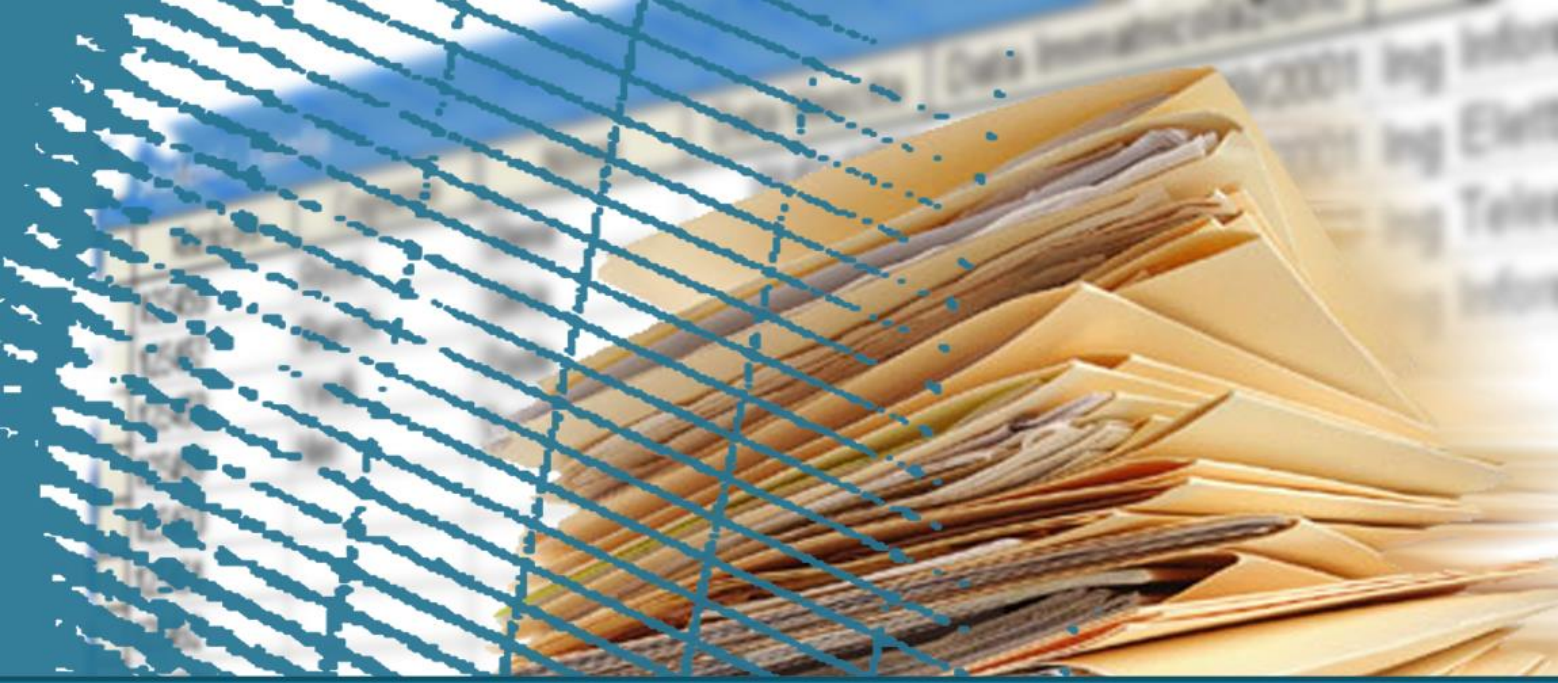
```
SELECT Column_Name, Num_Distinct, Num_Nulls
FROM USER_TAB_COL_STATISTICS
WHERE Table_Name = 'SP'
ORDER BY Column_Name;
```

Querying the data dictionary no.2 (2/2)

```
SELECT Column_Name, Num_Distinct, Num_Nulls
FROM USER_TAB_COL_STATISTICS
WHERE Table_Name = 'SP'
ORDER BY Column_Name;
```

R

Column_Name	Num_Distinct	Num_Nulls
SId	4	0
PId	6	0
Qty	4	0



Managing tables

Data integrity

Integrity constraints

- Data in a database are correct if they satisfy a set of correctness rules
  - rules are called *integrity constraints*
  - example: Qty >=0
- Data update operations define a new state for the database, which may not necessarily be correct

Integrity checks

- Checking the correctness of a database state may be done
  - by *application procedures*, performing all required checks
  - through the definition of *integrity constraints* on the tables
  - through the definition of *triggers*

Application procedures

- Each application includes all required correctness checks
- Pros
  - efficient approach
- Cons
  - checks may be circumvented by interacting directly with the DBMS
  - a coding error may have significant outcomes on the database
  - the knowledge of correctness rules is typically "hidden" inside applications

Table integrity constraints (1/2)

- Integrity constraints are
  - defined in the CREATE or ALTER TABLE statements
  - stored in the system data dictionary
- Each time data are updated, the DBMS automatically verifies that the constraints are satisfied

Table integrity constraints (2/2)

- Pros
  - *declarative* definition of constraints, whose verification is delegated to the system
    - the data dictionary describes all of the constraints in in the system
  - unique centralized check point
    - constraint verification may not be circumvented
- Cons
  - they may slow down application execution
  - it is not possible to define constraints of an arbitrary type
    - example: constraints on aggregated data

Triggers (1/2)

- Triggers are procedures executed automatically when specific data updates are performed
  - defined through the CREATE TRIGGER command
  - stored in the system data dictionary
- When a modification event occurs on data under the trigger's control, the procedure is automatically executed

Triggers (2/2)

- Pros
  - they allow defining complex constraints
    - normally used in combination with constraint definition on the tables
  - unique centralized check point
    - constraint verification may not be circumvented
- Cons
  - complex
  - they may slow down application execution

Fixing violations

- If an application tries to execute an operation that causes a constraint violation, the system may
  - block the operation, causing an error in the application execution
  - execute a compensating action so that a new correct state is reached
    - example: when a supplier is deleted, also delete its supplies

Integrity constraints in SQL-92

- The SQL-92 standard introduced the possibility to specify integrity constraints in a declarative way, delegating to the system the verification of their consistency
  - table constraints
    - restrictions on the data allowed in table columns
  - referential integrity constraints
    - manage references among different tables
      - based on the concept of foreign key

Table constraints (1/2)

- They may be defined on one or more table columns
- They are specified in the commands for creating
  - tables
  - domains
- Types of constraints
  - primary key
  - admissibility of the NULL value
  - uniqueness
  - general tuple constraints

Table constraints (2/2)

- They are verified after each SQL command operating on the table subject to the constraint
  - inserting new data
  - updating values in the columns subject to the constraint
- If the constraint is violated, the SQL command causing the violating generates an execution error

Primary key

- A primary key is a set of attributes that uniquely identifies rows in a tables
- Only one primary key may be specified for a given table
- Primary key definition
  - composed of a single attribute

    AttributeName Domain PRIMARY KEY

Primary key: example no. 1

```
CREATE TABLE S (SId          CHAR(5) PRIMARY KEY,
                SName        CHAR(20),
                #Employees   SMALLINT,
                City         CHAR(15));
```

Primary key

- A primary key is a set of attributes that uniquely identifies rows in a tables
- Only one primary key may be specified for a given table
- Primary key definition
  - composed of one or more attributes

PRIMARY KEY (*AttributeList*)

Primary key: example no. 2

```
CREATE TABLE SP (SId     CHAR(5),
                 PId     CHAR(6),
                 Qty     INTEGER
                 PRIMARY KEY (SId, PId));
```

Admissibility of the NULL value

- The NULL value indicates absence of information
- When a value must always be specified for a given attribute

  AttributeName Domain NOT NULL

  - the NULL value is not allowed

NOT NULL: example

```
CREATE TABLE S (SId          CHAR(5),
                SName        CHAR(20) NOT NULL,
                #Employees   SMALLINT,
                City         CHAR(15));
```

Uniqueness

- An attribute or a set of attributes may not take the same value in different rows of the table
  - for a single attribute

    AttributeName Domain UNIQUE
  - for one or more attributes

    UNIQUE (*AttributeList*)
- Repetition of the NULL value in multiple rows is allowed (it is seen as a different value in each row)

Candidate key

- A candidate key is a set of attributes that may serve as a primary key
  - it is unique
  - it might not allow the NULL value
- The combination UNIQUE NOT NULL allows defining a candidate key that does not allow null values

AttributeName Domain UNIQUE NOT NULL

Uniqueness: example

```
CREATE TABLE P ( PId      CHAR(6),
                 PName    CHAR(20) NOT NULL UNIQUE,
                 Color    CHAR(6),
                 Size     SMALLINT,
                 Store    CHAR(15));
```

General tuple constraints

- They allow expressing general conditions on each tuple
  - tuple or domain constraints

    AttributeName Domain CHECK (*Condition*)
  - predicates allowed in the WHERE clause may be specified as a condition
- The database is correct if the condition is true

General tuple constraints: example

```
CREATE TABLE S (SId             CHAR(5) PRIMARY KEY,
                SName           CHAR(20) NOT NULL,
                #Employees      SMALLINT
                                CHECK (#Employees>0),
                City            CHAR(15));
```

Referential integrity constraints

- They allow managing relationships among tables through the values of the attributes
- Example

S

SId	SName	#Employees	City

SP

SId	PId	Qty

  - column SId in SP may assume values that are already present in column SId in the S table
    - SId in SP: referencing column (or foreign key)
    - SId in S: referenced column (usually the primary key)

Foreign key definition

- A foreign key is defined in the CREATE TABLE statement of the referencing table

  FOREIGN KEY (*ReferencingAttributeList*)
  REFERENCES
  TableName [(*ReferencedAttributeList*)]

- If referencing attributes have the same name as the referenced attributes, they may be omitted

Foreign key definition: example

```
CREATE TABLE SP (SId      CHAR(5),
                 PId      CHAR(6),
                 Qty      INTEGER,
                 PRIMARY KEY (SId, PId),
                 FOREIGN KEY (SId)
                          REFERENCES S(SId),
                 FOREIGN KEY (PId)
                          REFERENCES P(PId));
```

Constraint management: example no.1

- SP (referencing table)
  - insert (new tuple)-> No
  - update (SId) -> No
  - delete (tuple) -> Ok
- S (referenced table)
  - insert (new tuple)-> Ok
  - update (SId) -> cascaded update (cascade)
  - delete (tuple) -> cascaded update (cascade)
    prevent action (no action)

Constraint management: example no.2 (1/3)

- Employees (EId, EName, City, DId)
- Departments (DId, DName, City)

Constraint management: example no.2 (2/3)

- Employees (referencing table)
  - insert (new tuple)-> No
  - update (DId) -> No
  - delete (tuple) -> Ok

Constraint management: example no.2 (3/3)

- Departments (referenced table)
  - insert (new tuple)-> Ok
  - update (DId) -> cascaded update (cascade)
  - delete (tuple) -> cascaded update (cascade)
    prevent action (no action)
    set to unknown value (set null)
    set to default value (set default)

Constraint management policies (1/3)

- Integrity constraints are checked after each SQL command that may cause their violation
- Insert or update operations on the referencing table that violate the constraints are not allowed

Constraint management policies (2/3)

- Update or delete operations on the referenced table have the following outcome on the referencing table:
  - CASCADE: the update or delete operation is propagated
  - SET NULL/DEFAULT: a null or default value is set in the columns for the tuples whose values are no longer present in the referenced table
  - NO ACTION: the offending action is not executed

Constraint management policies (3/3)

- In the CREATE TABLE statement of the referencing table

```
FOREIGN KEY  (ReferencingAttributeList )
REFERENCES
TableName [(ReferencedAttributeList)]
[ON UPDATE
<CASCADE | SET DEFAULT | SET NULL |
   NO ACTION>]
[ON DELETE
<CASCADE | SET DEFAULT | SET NULL |
   NO ACTION>]
```

Example database (1/4)

- supplier and product DB
  - table P: it describes available products
    - primary key: PId
    - the product name may not assume null or duplicate values
    - size is always greater than zero
  - table S: it describes suppliers
    - primary key: SId
    - the supplier name may not assume null or duplicate values
    - the number of employees is always greater than zero

Example database (1/4)

- supplier and product DB
  - table SP: it describes supplies, by relating products to the suppliers that provide them
    - primary key: (SId, PId)
    - quantity may not assume the null value and is greater than zero
    - referential integrity constraints

Example database (2/4)

```
CREATE TABLE P ( PId      CHAR(6) PRIMARY KEY,
                 PName    CHAR(20) NOT NULL UNIQUE,
                 Color    CHAR(6),
                 Size     SMALLINT
                          CHECK (Size > 0),
                 Store    CHAR(15));
```

Example database (3/4)

```
CREATE TABLE S (SId          CHAR(5) PRIMARY KEY,
                SName        CHAR(20) NOT NULL UNIQUE,
                #Employees   SMALLINT
                             CHECK (#Employees>0),
                City         CHAR(15));
```

Example database (4/4)

```
CREATE TABLE SP (SId        CHAR(5),
                 PId        CHAR(6),
                 Qty        INTEGER
                 CHECK (Qty IS NOT NULL and Qty>0),
                 PRIMARY KEY (SId, PId),
                 FOREIGN KEY (SId)
                             REFERENCES S(SId)
                 ON DELETE NO ACTION
                 ON UPDATE CASCADE,
                 FOREIGN KEY (PId)
                             REFERENCES P(PId)
                 ON DELETE NO ACTION
                 ON UPDATE CASCADE);
```