# 2.6 Other Data Models

- Logic-based data model (Deductive DBMS)
  - Extend the query function of DBMS (especially recursive query function)
  - Promote the deductive ability of DBMS
- Temporal data model
- Spatial data model
- XML data model
  - Store data on internet
  - Common data exchange standard
  - Information systems integration
  - Expression of semi-structured data
  - … …
- Others

# 2.7 Summary

- Data model is the core of a DBMS
- A data model is a methodology to simulate real world in database
- In fact, every kind of DBMS has implemented a data model

☹ If there will be a data model which can substitute relational model and become popular data model, just as relational model substituted hierarchical and network model 30 years ago **???**

# 3. User Interfaces and SQL Language*

# User interface of DBMS

- A DBMS must offer some interfaces to support user to access database, including:
  - Query Languages
  - Interface and maintaining tools (GUI)
  - APIs
  - Class Library
- Query Languages
  - Formal Query Language
  - Tabular Query Language
  - Graphic Query Language
  - Limited Natural Language Query Language

# Example of TQL & GQL

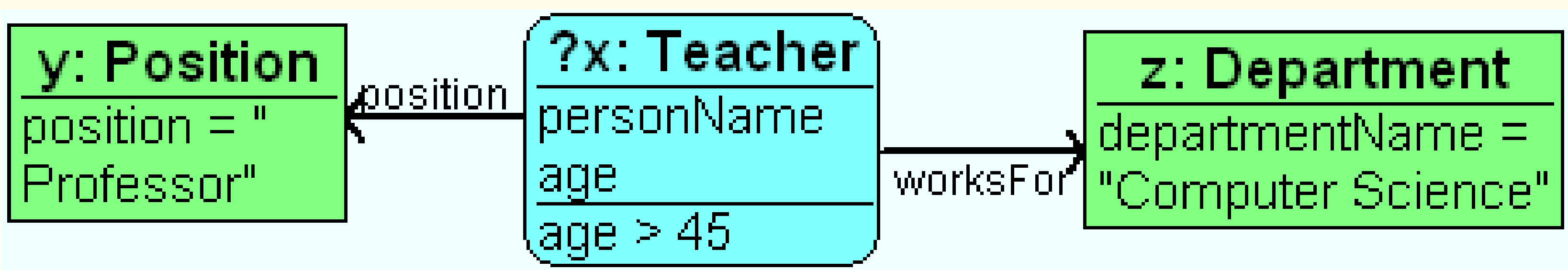
**Find the names of all students in the department of Info. Science**

| **Student** | <u>Sno</u> | Sname | Ssex | Sage | Sdept |
|---|---|---|---|---|---|
| | | P.<u>T</u> | | | IS |

操作符，表示打印（print）
实际是显示

示例元素，域变量

条件




**Find all Teachers, which have position=”Professor” and which have age>”45” and which work for department=”Computer Science”**

# Relational Query Languages

- Query languages:  Allow manipulation and retrieval of data from a database.
- Relational model supports simple, powerful QLs:
  - Strong formal foundation based on logic.
  - Allows for much optimization.
- Query Languages **!=** programming languages!
  - QLs not expected to be "Turing complete".
  - QLs not intended to be used for complex calculations.
  - QLs support easy, efficient access to large data sets.

# Formal Relational Query Languages

- Two mathematical Query Languages form the basis for "real" languages (e.g. SQL), and for implementation:
  - *Relational Algebra*: More operational, very useful for representing execution plans.
  - *Relational Calculus*: Lets users describe what they want, rather than how to compute it. (Non-operational, *declarative*.)
- The most successful relational database language --- SQL (Structured Query Language, Standard Query Language(1986))

# SQL Language

- It can be divided into four parts according to functions.
  - Data Definition Language (DDL), used to define, delete, or alter data schema.
  - Query Language (QL), used to retrieve data
  - Data Manipulation Language (DML), used to insert, delete, or update data.
  - Data Control Language (DCL), used to control user's access authority to data.
- QL and DML are introduced in detail in this chapter.

# SQL Language

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# Important terms and concepts

- Base table
- View
- Data type supported
- NULL
- UNIQUE
- DEFAULT
- PRIMARY KEY
- FOREIGN KEY
- CHECK (Integration Constraint)

# Example Instances

- We will use these instances of the Sailors, Reserves and Boats relations in our examples.

***R1***

| <u>sid</u> | <u>bid</u> | <u>day</u> |
|---|---|---|
| 22 | 101 | 10/10/96 |
| 58 | 103 | 11/12/96 |

***B1***

| <u>bid</u> | <u>bname</u> | <u>color</u> |
|---|---|---|
| 101 | tiger | red |
| 103 | lion | green |
| 105 | hero | blue |

***S1***

| <u>sid</u> | sname | rating | age |
|---|---|---|---|
| 22 | dustin | 7 | 45.0 |
| 31 | lubber | 8 | 55.5 |
| 58 | rusty | 10 | 35.0 |

***S2***

| <u>sid</u> | sname | rating | age |
|---|---|---|---|
| 28 | yuppy | 9 | 35.0 |
| 31 | lubber | 8 | 55.5 |
| 44 | guppy | 5 | 35.0 |
| 58 | rusty | 10 | 35.0 |

# Basic SQL Query

| | |
|---|---|
| SELECT | [DISTINCT] *target-list* |
| FROM | *relation-list* |
| WHERE | *qualification* |

- *relation-list* A list of relation names (possibly with a *range-variable* after each name).
- *target-list* A list of attributes of relations in *relation-list*
- *qualification* Comparisons combined using AND, OR and NOT.
- DISTINCT is an optional keyword indicating that the answer should not contain duplicates. Default is that duplicates are <u>*not*</u> eliminated!

# Conceptual Evaluation Strategy

- Semantics of an SQL query defined in terms of the following conceptual evaluation strategy:
  - Compute the cross-product of *relation-list*.
  - Discard resulting tuples if they fail *qualifications*.
  - Delete attributes that are not in *target-list*.
  - If DISTINCT is specified, eliminate duplicate rows.
- This strategy is probably the least efficient way to compute a query! An optimizer will find more efficient strategies to compute *the same answers*.

# Conceptual Evaluation Strategy

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  - Delete attributes that are not in *target-list*.
  - If DISTINCT is specified, eliminate duplicate rows.
- This strategy is probably the least efficient way to compute a query! An optimizer will find more efficient strategies to compute *the same answers*.

# Simple Example

```
SELECT  S.sname
FROM    Sailors S, Reserves R
WHERE   S.sid=R.sid AND R.bid=103
```

| (sid) | sname | rating | age | (sid) | bid | day |
|---|---|---|---|---|---|---|
| 22 | dustin | 7 | 45.0 | 22 | 101 | 10/10/96 |
| 22 | dustin | 7 | 45.0 | 58 | 103 | 11/12/96 |
| 31 | lubber | 8 | 55.5 | 22 | 101 | 10/10/96 |
| 31 | lubber | 8 | 55.5 | 58 | 103 | 11/12/96 |
| 58 | rusty | 10 | 35.0 | 22 | 101 | 10/10/96 |
| 58 | **rusty** | 10 | 35.0 | 58 | 103 | 11/12/96 |

**result**

# A Note on Range Variables

- Really needed only if the same relation appears twice in the FROM clause. The previous query can also be written as:

```
SELECT  S.sname
FROM    Sailors S, Reserves R
WHERE   S.sid=R.sid AND bid=103
```

OR

```
SELECT  sname
FROM    Sailors, Reserves
WHERE   Sailors.sid=Reserves.sid
        AND bid=103
```

*It is good style, however, to use range variables always!*

# Find sailors who've reserved at least one boat

```
SELECT  S.sid
FROM  Sailors S, Reserves R
WHERE  S.sid=R.sid
```

- Would adding DISTINCT to this query make a difference?
- What is the effect of replacing *S.sid* by *S.sname* in the SELECT clause? Would adding DISTINCT to this variant of the query make a difference?

# Expressions and Strings

```
SELECT  S.age, age1=S.age-5, 2*S.age AS age2
FROM  Sailors S
WHERE  S.sname LIKE 'B_%B'
```

- Illustrates use of arithmetic expressions and string pattern matching: *Find triples (of ages of sailors and two fields defined by expressions) for sailors whose names begin and end with B and contain at least three characters.*
- AS and = are two ways to name fields in result.
- LIKE is used for string matching. '_' stands for any one character and '%' stands for 0 or more arbitrary characters.

# Expressions and Strings

```
SELECT  S.age, age1=S.age-5, 2*S.age AS age2
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- AS and = are two ways to name fields in result.
- LIKE is used for string matching. '_' stands for any one character and '%' stands for 0 or more arbitrary characters.

# Find sid's of sailors who've reserved a red <u>or</u> a green boat

- UNION: Can be used to compute the union of any two *union-compatible* sets of tuples (which are themselves the result of SQL queries).
- If we replace OR by AND in the first version, what do we get?
- Also available: EXCEPT (What do we get if we replace UNION by EXCEPT?)

```
SELECT  S.sid
FROM  Sailors S, Boats B, Reserves R
WHERE  S.sid=R.sid AND R.bid=B.bid
  AND (B.color='red' OR B.color='green')
```

```
SELECT  S.sid
FROM  Sailors S, Boats B, Reserves R
WHERE  S.sid=R.sid AND R.bid=B.bid
            AND B.color='red'
UNION
SELECT  S.sid
FROM  Sailors S, Boats B, Reserves R
WHERE  S.sid=R.sid AND R.bid=B.bid
            AND B.color='green'
```

# Find sid's of sailors who've reserved a red and a green boat

- INTERSECT: Can be used to compute the intersection of any two *union-compatible* sets of tuples.
- Included in the SQL/92 standard, but some systems don't support it.
- Contrast symmetry of the UNION and INTERSECT queries with how much the other versions differ.

```
SELECT  S.sid
FROM  Sailors S, Boats B1, Reserves R1,
        Boats B2, Reserves R2
WHERE  S.sid=R1.sid AND R1.bid=B1.bid
   AND  S.sid=R2.sid  AND R2.bid=B2.bid
   AND (B1.color='red' AND
          B2.color='green')
```

```
SELECT  S.sid
FROM  Sailors S, Boats B, Reserves R
WHERE  S.sid=R.sid AND R.bid=B.bid
          AND B.color='red'
INTERSECT
SELECT  S.sid
FROM  Sailors S, Boats B, Reserves R
WHERE  S.sid=R.sid AND R.bid=B.bid
          AND B.color='green'
```

# Nested Queries

*Find names of sailors who've reserved boat #103:*

```
SELECT  S.sname
FROM  Sailors S
WHERE  S.sid IN  (SELECT  R.sid
                  FROM  Reserves R
                  WHERE  R.bid=103)
```

- A very powerful feature of SQL: a WHERE clause can itself contain an SQL query! (Actually, so can FROM and HAVING clauses.)
- To find sailors who've *not* reserved #103, use NOT IN.
- To understand semantics of nested queries, think of a *nested loops* evaluation: *For each Sailors tuple, check the qualification by computing the subquery.*

# Nested Queries with Correlation

*Find names of sailors who've reserved boat #103:*

```
SELECT  S.sname
FROM    Sailors S
WHERE   EXISTS  (SELECT  *
                 FROM  Reserves R
                 WHERE  R.bid=103 AND S.sid=R.sid)
```

- EXISTS is another set comparison operator, like IN.
- Illustrates why, in general, subquery must be re-computed for each Sailors tuple.
- How to *find names of sailors who've reserved boat #103 and reserved only one time*?

# Nested Queries with Correlation

- *Find IDs of boats which are reserved by only one sailor.*

```
SELECT bid
FROM Reserves R1
WHERE bid NOT IN (
        SELECT bid
        FROM Reserves R2
        WHERE R2.sid ¬= R1.sid)
```

# More on Set-Comparison Operators

- We've already seen IN, EXISTS and UNIQUE. Can also use NOT IN, NOT EXISTS and NOT UNIQUE.
- Also available: *op* ANY, *op* ALL, *op* IN $<, >, =, \leq, \geq, \neq$
- *Find sailors whose rating is greater than that of some sailor called Horatio*:

```
SELECT  *
FROM  Sailors S
WHERE  S.rating > ANY  (SELECT  S2.rating
                        FROM  Sailors S2
                        WHERE S2.sname='Horatio')
```

# Rewriting INTERSECT Queries Using IN

*Find sid's of sailors who've reserved both a red and a green boat:*

```
SELECT  S.sid
FROM  Sailors S, Boats B, Reserves R
WHERE  S.sid=R.sid AND R.bid=B.bid AND B.color='red'
          AND S.sid IN  (SELECT  S2.sid
                         FROM  Sailors S2, Boats B2, Reserves R2
                         WHERE  S2.sid=R2.sid AND R2.bid=B2.bid
                                AND  B2.color='green')
```

- Similarly, EXCEPT queries re-written using NOT IN.
- To find *names* (not *sid*'s) of Sailors who've reserved both red and green boats, just replace *S.sid* by *S.sname* in SELECT clause. (What about INTERSECT query?)

# Division in SQL

*Find sailors who've reserved all boats.*

Solution 1:

```
SELECT  S.sname
FROM  Sailors S
WHERE  NOT EXISTS
          ((SELECT  B.bid
             FROM  Boats B)
            EXCEPT
             (SELECT  R.bid
              FROM  Reserves R
              WHERE  R.sid=S.sid))
```

# Division in SQL

*Find sailors who've reserved all boats.*

Solution 1:

```
SELECT  S.sname
FROM  Sailors S
WHERE  NOT EXISTS
          ((SELECT  B.bid
            FROM  Boats B)
           EXCEPT
            (SELECT  R.bid
             FROM  Reserves R
             WHERE  R.sid=S.sid))
```

# Division in SQL

Solution 2:

Let's do it the hard way, without EXCEPT:

```
SELECT  S.sname
FROM  Sailors S
WHERE  NOT EXISTS  (SELECT  B.bid
                    FROM  Boats B
                    WHERE  NOT EXISTS  (SELECT  R.bid
                                        FROM  Reserves R
                                        WHERE  R.bid=B.bid
                                          AND R.sid=S.sid))
```

*Sailors S such that ...*

*there is no boat B without ...*

*a Reserves tuple showing S reserved B*

# Aggregate Operators

- Significant extension of relational algebra.
  - COUNT (*)
  - COUNT ( [DISTINCT] A)
  - SUM ( [DISTINCT] A)
  - AVG ( [DISTINCT] A)
  - MAX (A)
  - MIN (A)
- *A* is single column

# Examples of Aggregate Operators

```
SELECT  COUNT (*)
FROM  Sailors S
```

```
SELECT  COUNT (DISTINCT S.rating)
FROM  Sailors S
WHERE S.sname='Bob'
```

```
SELECT  AVG (S.age)
FROM  Sailors S
WHERE  S.rating=10
```

```
SELECT  AVG (DISTINCT S.age)
FROM  Sailors S
WHERE  S.rating=10
```

```
SELECT  S.sname
FROM  Sailors S
WHERE  S.rating= (SELECT  MAX(S2.rating)
                  FROM  Sailors S2)
```

# Find name and age of the oldest sailor(s)

- The first query is illegal! (We'll look into the reason a bit later, when we discuss GROUP BY.)
- The third query is equivalent to the second query, and is allowed in the SQL/92 standard, but is not supported in some systems.

```
SELECT  S.sname, MAX (S.age)
FROM  Sailors S
```

```
SELECT  S.sname, S.age
FROM  Sailors S
WHERE  S.age =
        (SELECT  MAX (S2.age)
         FROM  Sailors S2)
```

```
SELECT  S.sname, S.age
FROM  Sailors S
WHERE  (SELECT  MAX (S2.age)
         FROM  Sailors S2)
        = S.age
```

# Motivation for Grouping

- So far, we've applied aggregate operators to all (qualifying) tuples. Sometimes, we want to apply them to each of several *groups* of tuples.
- Consider: *Find the age of the youngest sailor for each rating level.*
  - In general, we don't know how many rating levels exist, and what the rating values for these levels are!
  - Suppose we know that rating values go from 1 to 10; we can write 10 queries that look like this (!):

For $i$ = 1, 2, … , 10:

```
SELECT  MIN (S.age)
FROM  Sailors S
WHERE  S.rating = i
```

# Queries With GROUP BY and HAVING

```
SELECT      [DISTINCT] target-list
FROM        relation-list
WHERE       qualification
GROUP BY    grouping-list
HAVING      group-qualification
```

- The *target-list* contains
  - (i) attribute names
  - (ii) terms with aggregate operations (e.g., MIN (*S.age*)).
- The attribute list (i) must be a subset of *grouping-list*. Intuitively, each answer tuple corresponds to a *group*, and these attributes must have a single value per group. (A *group* is a set of tuples that have the same value for all attributes in *grouping-list*.)

# Queries With GROUP BY and HAVING

SELECT [DISTINCT] *target-list*
FROM *relation-list*
WHERE *qualification*
GROUP BY *grouping-list*
HAVING *group-qualification*

- The *target-list* contains
  - (i) attribute names
  - (ii) terms with aggregate operations (e.g., MIN (*S.age*)).
- The attribute list (i) must be a subset of *grouping-list*. Intuitively, each answer tuple corresponds to a *group*, and these attributes must have a single value per group. (A *group* is a set of tuples that have the same value for all attributes in *grouping-list*.)

# Conceptual Evaluation

- The cross-product of *relation-list* is computed, tuples that fail *qualification* are discarded, '*unnecessary*' fields are deleted, and the remaining tuples are partitioned into groups by the value of attributes in *grouping-list*.
- The *group-qualification* is then applied to eliminate some groups. Expressions in *group-qualification* must have a *single value per group*!
  - In fact, an attribute in *group-qualification* that is not an argument of an aggregate op also appears in *grouping-list*. (SQL does not exploit primary key semantics here!)
- One answer tuple is generated per qualifying group.

# Find age of the youngest sailor with age ≥ 18, for each rating with at least 2 <u>such</u> sailors

```
SELECT  S.rating,  MIN (S.age) AS minage
FROM  Sailors S
WHERE  S.age >= 18
GROUP BY  S.rating
HAVING  COUNT (*) > 1
```

*Sailors instance:*

| <u>sid</u> | sname | rating | age |
|---|---|---|---|
| 22 | dustin | 7 | 45.0 |
| 29 | brutus | 1 | 33.0 |
| 31 | lubber | 8 | 55.5 |
| 32 | andy | 8 | 25.5 |
| 58 | rusty | 10 | 35.0 |
| 64 | horatio | 7 | 35.0 |
| 71 | zorba | 10 | 16.0 |
| 74 | horatio | 9 | 35.0 |
| 85 | art | 3 | 25.5 |
| 95 | bob | 3 | 63.5 |
| 96 | frodo | 3 | 25.5 |

*Answer relation:*

| rating | minage |
|---|---|
| 3 | 25.5 |
| 7 | 35.0 |
| 8 | 25.5 |

# Find age of the youngest sailor with age ≥ 18, for each rating with at least 2 such sailors.

| rating | age |
|---|---|
| 7 | 45.0 |
| 1 | 33.0 |
| 8 | 55.5 |
| 8 | 25.5 |
| 10 | 35.0 |
| 7 | 35.0 |
| 10 | 16.0 |
| 9 | 35.0 |
| 3 | 25.5 |
| 3 | 63.5 |
| 3 | 25.5 |

| rating | age |
|---|---|
| 1 | 33.0 |
| 3 | 25.5 |
| 3 | 63.5 |
| 3 | 25.5 |
| 7 | 45.0 |
| 7 | 35.0 |
| 8 | 55.5 |
| 8 | 25.5 |
| 9 | 35.0 |
| 10 | 35.0 |

| rating | minage |
|---|---|
| 3 | 25.5 |
| 7 | 35.0 |
| 8 | 25.5 |

**Find age of the youngest sailor with age ≥ 18, for each rating with at least 2 such sailors and with every sailor under 60.**

HAVING COUNT (*) > 1 AND EVERY (S.age <=60)

| rating | age |
|---|---|
| 7 | 45.0 |
| 1 | 33.0 |
| 8 | 55.5 |
| 8 | 25.5 |
| 10 | 35.0 |
| 7 | 35.0 |
| 10 | 16.0 |
| 9 | 35.0 |
| 3 | 25.5 |
| 3 | 63.5 |
| 3 | 25.5 |

| rating | age |
|---|---|
| 1 | 33.0 |
| 3 | 25.5 |
| 3 | 63.5 |
| 3 | 25.5 |
| 7 | 45.0 |
| 7 | 35.0 |
| 8 | 55.5 |
| 8 | 25.5 |
| 9 | 35.0 |
| 10 | 35.0 |

| rating | minage |
|---|---|
| 7 | 35.0 |
| 8 | 25.5 |

What is the result of changing EVERY to ANY?

# For each red boat, find the number of reservations for this boat

```
SELECT  B.bid,  COUNT (*) AS scount
FROM  Boats B, Reserves R
WHERE  R.bid=B.bid AND B.color='red'
GROUP BY  B.bid
```

- Grouping over a join of two relations.
- What do we get if we remove *B.color='red'* from the WHERE clause and add a HAVING clause with this condition?

# For each red boat, find the number of reservations for this boat

```
SELECT  B.bid,  COUNT (*) AS scount
FROM  Boats B, Reserves R
WHERE  R.bid=B.bid AND B.color='red'
GROUP BY  B.bid
```

- Grouping over a join of two relations.
- What do we get if we remove *B.color='red'* from the WHERE clause and add a HAVING clause with this condition?

## Find age of the youngest sailor with age > 18, for each rating with at least 2 sailors (of any age)

```
SELECT  S.rating,  MIN (S.age)
FROM  Sailors S
WHERE  S.age > 18
GROUP BY  S.rating
HAVING  1 < (SELECT  COUNT (*)
             FROM  Sailors S2
             WHERE  S2.rating = S.rating)
```

| rating | minage |
|---|---|
| 3 | 25.5 |
| 7 | 35.0 |
| 8 | 25.5 |
| 10 | 35.5 |

- Shows HAVING clause can also contain a sub-query.
- Compare this with the query where we considered only ratings with 2 sailors over 18!
- What if HAVING clause is replaced by:
  - HAVING COUNT(*) >1

# Find those ratings for which the average age is the minimum over all ratings

- Aggregate operations cannot be nested! WRONG:

```
SELECT S.rating
FROM Sailors S
WHERE S.age = (SELECT MIN (AVG (S2.age))
               FROM Sailors S2)
```

- Correct solution (in SQL/92):

```
SELECT Temp.rating
FROM (SELECT S.rating, AVG (S.age) AS avgage
      FROM Sailors S
      GROUP BY S.rating) AS Temp
WHERE Temp.avgage = (SELECT MIN (Temp.avgage)
                     FROM Temp)
```

## Find those ratings for which the average age is the minimum over all ratings

- Aggregate operations cannot be nested! WRONG:

```
SELECT  S.rating
FROM  Sailors S
WHERE  S.age = (SELECT  MIN (AVG (S2.age))
                        FROM Sailors S2)
```

- Correct solution (in SQL/92):

```
SELECT  Temp.rating
FROM  (SELECT  S.rating, AVG (S.age) AS avgage
           FROM  Sailors S
           GROUP BY  S.rating) AS Temp
WHERE  Temp.avgage = (SELECT  MIN (Temp.avgage)
                                  FROM  Temp)
```

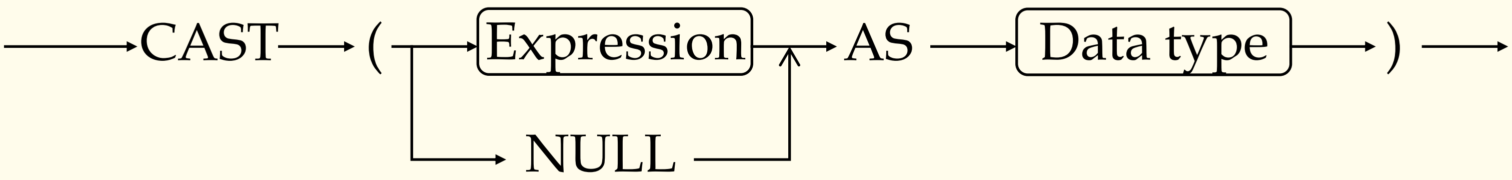
# Null Values

- Field values in a tuple are sometimes *unknown* (e.g., a rating has not been assigned) or *inapplicable* (e.g., no spouse's name).
  - SQL provides a special value *null* for such situations.
- The presence of *null* complicates many issues. E.g.:
  - Special operators needed to check if value is/is not *null*.
  - Is *rating*>*8* true or false when *rating* is equal to *null*? What about AND, OR and NOT connectives?
  - We need a 3-valued logic (true, false and *unknown*).
  - Meaning of constructs must be defined carefully. (e.g., WHERE clause eliminates rows that don't evaluate to true.)
  - New operators (in particular, *outer joins*) possible/needed.

# Some New Features of SQL

- **CAST expression**
- CASE expression
- Sub-query
- Outer Join
- Recursion

# CAST Expression




- Change the expression to the target data type
- Valid target type
- Use
  - Match function parameters

    substr(string1, CAST(x AS Integer), CAST(y AS Integer))
  - Change precision while calculating

    CAST (elevation AS Decimal (5,0))
  - Assign a data type to NULL value

# CAST Expression

- Example:

Students (name, school)

Soldiers (name, service)

```
CREATE VIEW prospects (name, school, service) AS
    SELECT name, school, CAST(NULL AS Varchar(20))
    FROM Students
UNION
    SELECT name, CAST(NULL AS Varchar(20)), service
    FROM Soldiers ;
```

# Some New Features of SQL

- CAST expression
- **CASE expression**
- Sub-query
- Outer Join
- Recursion

# CASE Expression

- Simple form :

  Officers (name, status, rank, title)

```
SELECT name, CASE status
                WHEN 1 THEN 'Active Duty'
                WHEN 2 THEN 'Reserve'
                WHEN 3 THEN 'Special Assignment'
                WHEN 4 THEN 'Retired'
                ELSE 'Unknown'
            END AS status
FROM Officers ;
```

# CASE Expression

- General form (use searching condition):

  Machines (serialno, type, year, hours_used, accidents)

- *Find the rate of the accidents of "chain saw" in the whole accidents :*

```
SELECT sum (CASE
                WHEN type='chain saw' THEN accidents
                ELSE 0e0
            END) / sum (accidents)
FROM Machines;
```

# CASE Expression

- *Find the average accident rate of every kind of equipment :*

```
SELECT type, CASE
                    WHEN sum(hours_used)>0 THEN
                         sum(accidents)/sum(hours_used)
                    ELSE NULL
               END AS accident_rate
FROM Machines
GROUP BY type;
```

(Because some equipments maybe not in use at all, their hours_used is 0. Use CASE can prevent the expression divided by 0.)

# CASE Expression

- Compared with

```
SELECT type, sum(accidents)/sum(hours_used)
FROM Machines
GROUP BY type
HAVING sum(hours_used)>0;
```

# CASE Expression

- General form (use searching condition):

  Machines (serialno, type, year, hours_used, accidents)

- *Find the rate of the accidents of "chain saw" in the whole accidents :*

```
SELECT sum (CASE
                WHEN type='chain saw' THEN accidents
                ELSE 0e0
            END) / sum (accidents)
FROM Machines;
```

# CASE Expression

- *Find the average accident rate of every kind of equipment :*

```
SELECT type, CASE
              WHEN sum(hours_used)>0 THEN
                   sum(accidents)/sum(hours_used)
              ELSE NULL
          END AS accident_rate
FROM Machines
GROUP BY type;
```

(Because some equipments maybe not in use at all, their hours_used is 0. Use CASE can prevent the expression divided by 0.)

# CASE Expression

- Compared with

```
SELECT type, sum(accidents)/sum(hours_used)
FROM Machines
GROUP BY type
HAVING sum(hours_used)>0;
```

# Some New Features of SQL

- CAST expression
- CASE expression
- **Sub-query**
- Outer Join
- Recursion

# Sub-query

- Embedded query & embedded query with correlation
- The functions of sub-queries have been enhanced in new SQL standard. Now they can be used in SELECT and FROM clause
  - Scalar sub-query
  - Table expression
  - Common table expression

# Scalar Sub-query

- The result of a sub-query is a single value. It can be used in the place where a value can occur.
- *Find the departments whose average bonus is higher than average salary :*

```
SELECT d.deptname, d.location
FROM dept AS d
WHERE (SELECT avg(bonus)
             FORM emp
             WHERE deptno=d.deptno)
        > (SELECT avg(salary)
             FORM emp
             WHERE deptno=d.deptno)
```

# Scalar Sub-query

- *List the deptno, deptname, and the max salary of all departments located in New York :*

```
SELECT d.deptno, d.deptname, (SELECT MAX (salary)
                              FROM emp
                              WHERE deptno=d.deptno) AS maxpay
FROM dept AS d
WHERE d.location = 'New York' ;
```

# Table Expression

- The result of a sub-query is a table. It can be used in the place where a table can occur.

```
SELECT startyear, avg(pay)
FROM (SELECT name, salay+bonus AS pay,
                    year(startdate) AS startyear
          FROM emp) AS emp2
GROUP BY startyear;
```

- *Find departments whose total payment is greater than 200000*

```
SELECT deptno, totalpay
FROM (SELECT deptno, sum(salay)+sum(bonus) AS totalpay
          FROM emp
          GROUP BY deptno) AS payroll
WHERE totalpay>200000;
```

- Table expressions are temporary views in fact.

# Table Expression

- The result of a sub-query is a table. It can be used in the place where a table can occur.

```
SELECT startyear, avg(pay)
FROM (SELECT name, salay+bonus AS pay,
                    year(startdate) AS startyear
          FROM emp) AS emp2
GROUP BY startyear;
```

- *Find departments whose total payment is greater than 200000*

```
SELECT deptno, totalpay
FROM (SELECT deptno, sum(salay)+sum(bonus) AS totalpay
          FROM emp
          GROUP BY deptno) AS payroll
WHERE totalpay>200000;
```

- Table expressions are temporary views in fact.

# Common Table Expression

- In some complex query, a table expression may need occurring more than one time in the same SQL statements. Although it is permitted, the efficiency is low and there maybe inconsistency problem.
- WITH clause can be used to define a common table expression. In fact, it defines a temporary view.
- *Find the department who has the highest total payment :*

# Common Table Expression

- *Find the department who has the highest total payment :*

```
WITH payroll (deptno, totalpay) AS
     (SELECT deptno, sum(salary)+sum(bonus)
     FROM emp
     GROUP BY deptno)
SELECT deptno
FROM payroll
WHERE totalpay = (SELECT max(totalpay)
                  FROM payroll);
```

- Common table expression mainly used in queries which need multi level focuses.

# Common Table Expression

- *Find department pairs, in which the first department's average salary is more than two times of the second one's :*

```
WITH deptavg (deptno, avgsal) AS
      (SELECT deptno, avg(salary)
      FROM emp
      GROUP BY deptno)
SELECT d1.deptno, d1.avgsal, d2.deptno, d2.avgsal
FROM deptavg AS d1, deptavg AS d2
WHERE d1.avgsal>2*d2.avgsal;
```

# Some New Features of SQL

- CAST expression
- CASE expression
- Sub-query
- **Outer Join**
- Recursion

# Outer Join

Teacher ( name, rank )
Course (subject, enrollment, quarter, teacher)

```
WITH
    innerjoin(name, rank, subject, enrollment) AS
        (SELECT t.name, t.rank, c.subject, c.enrollment
         FROM teachers AS t, courses AS c
         WHERE t.name=c.teacher AND c.quarter='Fall 96') ,
    teacher-only(name, rank) AS
        (SELECT name, rank
         FROM teachers
         EXCEPT ALL
         SELECT name, rank
         FROM innerjoin) ,
    course-only(subject, enrollment) AS
        (SELECT subject, enrollment
         FROM courses
         EXCEPT ALL
         SELECT subject, enrollment
         FROM innerjoin)
```

# Outer Join

```
SELECT name, rank, subject, enrollment
FROM innerjoin
UNION ALL
SELECT name, rank,
        CAST (NULL AS Varchar(20)) AS subject,
        CAST (NULL AS Integer) AS enrollment
FROM teacher-only
UNION ALL
SELECT CAST (NULL AS Varchar(20)) AS name,
        CAST (NULL AS Varchar(20)) AS rank,
        subject, enrollment
FROM course-only ;
```

# Outer Join

Teacher ( name, rank )
Course (subject, enrollment, quarter, teacher)

```
WITH
    innerjoin(name, rank, subject, enrollment) AS
        (SELECT t.name, t.rank, c.subject, c.enrollment
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    teacher-only(name, rank) AS
        (SELECT name, rank
         FROM teachers
         EXCEPT ALL
         SELECT name, rank
         FROM innerjoin) ,
    course-only(subject, enrollment) AS
        (SELECT subject, enrollment
         FROM courses
         EXCEPT ALL
         SELECT subject, enrollment
         FROM innerjoin)
```

# Outer Join

```
SELECT name, rank, subject, enrollment
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UNION ALL
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       subject, enrollment
FROM course-only ;
```

# Some New Features of SQL

- CAST expression
- CASE expression
- Sub-query
- Outer Join
- **Recursion**

# Recursion

- If a common table expression uses itself in its definition, this is called recursion. It can calculate a complex recursive inference in one SQL statement.

  **FedEmp** (name, salary, manager)

- *Find all employees under the management of Hoover and whose salary is more than 100000*

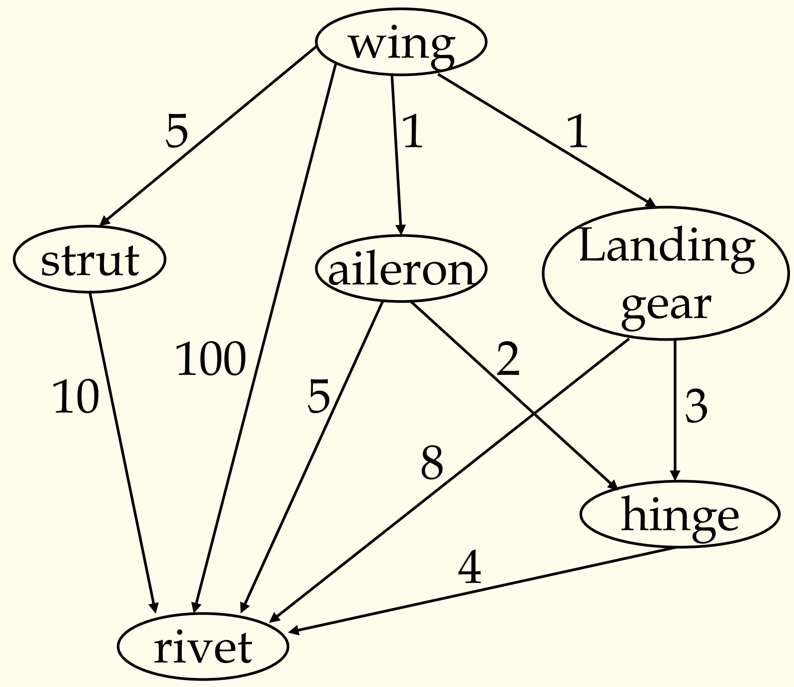
```
WITH agents (name, salary) AS
      ((SELECT name, salary                    --- initial query
        FROM FedEmp
        WHERE manager='Hoover')
      UNION ALL
       (SELECT f.name, f.salary                --- recursive query
        FROM agents AS a, FedEmp AS f
        WHERE f.manager = a.name))
SELECT name                                    --- final query
FROM agents
WHERE salary>100000 ;
```

# Recursive Calculation

- A classical "parts searching problem"

Components

| Part | Subpart | QTY |
|---|---|---|
| wing | strut | 5 |
| wing | aileron | 1 |
| wing | landing gear | 1 |
| wing | rivet | 100 |
| strut | rivet | 10 |
| aileron | hinge | 2 |
| aileron | rivet | 5 |
| landing gear | hinge | 3 |
| landing gear | rivet | 8 |
| hinge | rivet | 4 |




Directed acyclic graph, which assures the recursion can be stopped

# Recursive Calculation

- *Find how much rivets are used in one wing?*
- A temporary view is defined to show the list of each subpart's quantity used in a specified part :

```
WITH wingpart (subpart, qty) AS
    ((SELECT subpart, qty              ---initial query
      FROM components
      WHERE part='wing')
    UNION ALL
     (SELECT c.subpart, w.qty*c.qty  ---recursive qry
      FROM wingpart w, components c
      WHERE w.subpart=c.part))
```

wingpart

| Subpart | QTY | |
|---|---|---|
| strut | 5 | Used directly |
| aileron | 1 | Used directly |
| landing gear | 1 | Used directly |
| rivet | 100 | Used directly |
| rivet | 50 | Used on strut |
| hinge | 2 | Used on aileron |
| rivet | 5 | Used on aileron |
| hinge | 3 | on landing gear |
| rivet | 8 | on landing gear |
| rivet | 8 | on aileron hinges |
| rivet | 12 | on L G hinges |

# Recursive Calculation

- *Find how much rivets are used in one wing?*
- A temporary view is defined to show the list of each subpart's quantity used in a specified part :

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      WHERE w.subpart=c.part))
```

wingpart

| Subpart | QTY | |
|---|---|---|
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| aileron | 1 | Used directly |
| landing gear | 1 | Used directly |
| rivet | 100 | Used directly |
| rivet | 50 | Used on strut |
| hinge | 2 | Used on aileron |
| rivet | 5 | Used on aileron |
| hinge | 3 | on landing gear |
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| rivet | 8 | on aileron hinges |
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# Recursive Calculation

- *Find how much rivets are used in one wing?*

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WITH wingpart (subpart, qty) AS
        ((SELECT subpart, qty                    ---initial query
          FROM components
          WHERE part='wing')
        UNION ALL
         (SELECT c.subpart, w.qty*c.qty           ---recursive qry
          FROM wingpart w, components c
          WHERE w.subpart=c.part))
SELECT sum(qty) AS qty
FROM wingpart
WHERE subpart='rivet' ;
```

- The result is :

| qty |
|---|
| 183 |

# Recursive Calculation

- *Find all subparts and their total quantity needed to assemble a wing :*

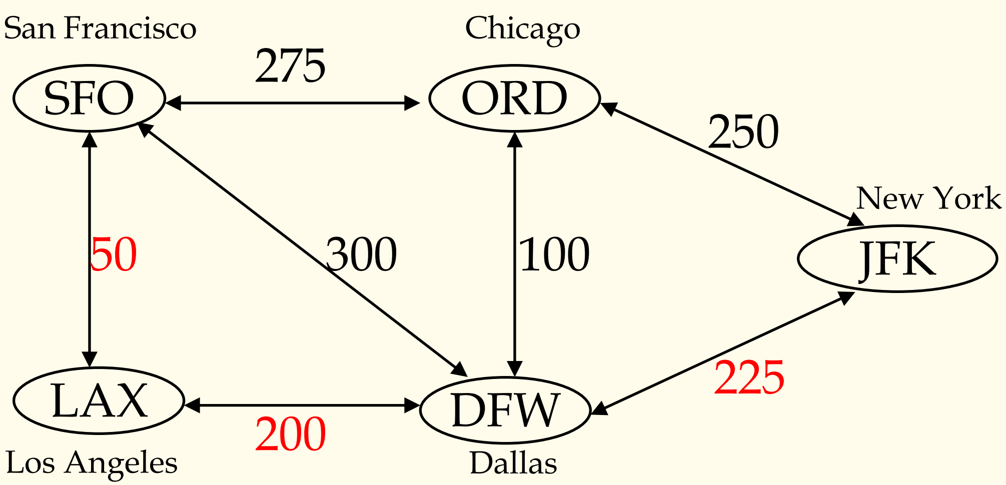
```
WITH wingpart (subpart, qty) AS
        ((SELECT subpart, qty                   ---initial query
          FROM components
          WHERE part='wing')
        UNION ALL
         (SELECT c.subpart, w.qty*c.qty ---recursive qry
          FROM wingpart w, components c
          WHERE w.subpart=c.part))
SELECT subpart, sum(qty) AS qty
FROM wingpart
Group BY  subpart ;
```

- The result is :

| subpart | qty |
|---|---|
| strut | 5 |
| aileron | 1 |
| landing gear | 1 |
| hinge | 5 |
| rivet | 183 |

# Recursive Search

- Typical airline route searching problem
- *Find the lowest total cost route from SFO to JFK*




Flights

| FlightNo | Origin | Destination | Cost |
|---|---|---|---|
| HY 120 | DFW | JFK | 225 |
| HY 130 | DFW | LAX | 200 |
| HY 140 | DFW | ORD | 100 |
| HY 150 | DFW | SFO | 300 |
| HY 210 | JFK | DFW | 225 |
| HY 240 | JFK | ORD | 250 |
| HY 310 | LAX | DFW | 200 |
| HY 350 | LAX | SFO | 50 |
| HY 410 | ORD | DFW | 100 |
| HY 420 | ORD | JFK | 250 |
| HY 450 | ORD | SFO | 275 |
| HY 510 | SFO | DFW | 300 |
| HY 530 | SFO | LAX | 50 |
| HY 540 | SFO | ORD | 275 |

# Recursive Search

```
WITH trips (destination, route, nsegs, totalcost) AS
    ((SELECT destination, CAST(destination AS varchar(20)), 1, cost
      FROM flights                                          --- initial query
      WHERE origin='SFO')
    UNION ALL
     (SELECT f.destination,                                 --- recursive query
             CAST(t.route||','||f.destination AS varchar(20)),
             t.nsegs+1, t.totalcost+f.cost
      FROM trips t, flights f
      WHERE t.destination=f.origin
             AND f.destination<>'SFO'                       --- stopping rule 1
             AND f.origin<>'JFK'                            --- stopping rule 2
             AND t.nsegs<=3))                               --- stopping rule 3
SELECT route,  totalcost                                    --- final query
FROM trips
WHERE destination='JFK' AND totalcost=                      --- lowest cost rule
                              (SELECT min(totalcost)
                               FROM trips
                               WHERE destination='JFK') ;
```

## 3.6.2 临时视图和递归查询

在复杂查询中，将查询中相对独立部分作为查询的中间结果，定义临时视图。

**临时视图与普通视图的区别：**

- 功能相同，但临时视图仅用于附在临时定义后的查询语句中；
- 查询语句结束，临时视图便不在存在，不需用DROP VIEW去撤消。
- 创建临时视图只需将CREATE VIEW改为WITH。

递归查询的应用很多，例如查询某门课程的先修课程等。

传统的SQL难以表示递归查询，目前主要的DBMS产品和SQL:1999之后的标准都增加了递归查询功能。

例如：设x, y, z是点，ARC(x, y)是具有属性x, y的基表，其中每个元组表示x到y的弧线。点之间可以通过弧线构成路径，路径可以是单个弧线，也可以是多个弧线首尾相连而成。

设PATH(x,y)是具有x,y属性的路径表，其中，每个元组表示x到y的一条路经。

用SQL查询所有点间的路径，这是一个递归查询。

```
WITH RECURSIVE PATH(x,y) AS
/*通过递规定义临时视图PATH(x,y)*/
((SELECT * FROM ARC)
UNION
(SELECT PATH.x,ARC.y FROM PATH,ARC
WHERE PATH.y=ARC.x))
```

PATH出现在
PATH定义中，
属于递归定义

PATH初始值为空，递归到
PATH无变化为止

查询语句：

SELECT * FROM PATH

临时视图和普通视图一样，也可以在其上进行较复杂的查询。可用WHERE语句进行限制。

限制条件应尽可能的加在临时视图中，因为生成临时视图的计算量要远大于查询语句的计算量，而且临时视图变小了，查询语句的计算量也将相应的减小。

只取从A出发的弧线

```
WITH RECURSIVE PATH(x,y) AS
((SELECT * FROM ARC WHERE x='A')
UNION
(SELECT PATH.x,ARC.y FROM PATH,ARC
WHERE PATH.y=ARC.x))
```

查询从A点到其它点的路径。

## 语句1：

```
SELECT  SNAME
  FROM      SC AS X, SC AS Y,STUDENT
    WHERE  X.SNO=STUDENT.SNO
       AND  X.SNO=Y.SNO
       AND  X.GRADE > 90
       AND  Y.GRADE>90
       AND  X.CNO IN (SELECT CNO FROM COUSE WHERE SEMESTER = '秋' )
       AND  Y.CNO IN (SELECT CNO FROM COUSE WHERE SEMESTER = '秋' )
```

## 语句2：

```
SELECT  SNAME
 FROM    STUDENT
     WHERE  SNO IN
     (SELECT SNO
          FROM CS
          WHERE GRADE > 90 AND
          CNO IN (SELECT CNO
                        FROM COUSE
                        WHERE SEMESTER = '秋'
     GROUP BY SNO
          HAVING COUNT(*)>=2)
```

# Recursive Search

```
WITH trips (destination, route, nsegs, totalcost) AS
    ((SELECT destination, CAST(destination AS varchar(20)), 1, cost
     FROM flights                                              --- initial query
     WHERE origin='SFO')
    UNION ALL
     (SELECT f.destination,                                    --- recursive query
             CAST(t.route||','||f.destination AS varchar(20)),
             t.nsegs+1, t.totalcost+f.cost
     FROM trips t, flights f
     WHERE t.destination=f.origin
             AND f.destination<>'SFO'                          --- stopping rule 1
             AND f.origin<>'JFK'                               --- stopping rule 2
             AND t.nsegs<=3))                                  --- stopping rule 3
SELECT route,  totalcost                                       --- final query
FROM trips
WHERE destination='JFK' AND totalcost=                         --- lowest cost rule
                        (SELECT min(totalcost)
                         FROM trips
                         WHERE destination='JFK') ;
```

# Result

Trips

| Destination | Route | Nsegs | Totalcost |
|---|---|---|---|
| DFW | DFW | 1 | 300 |
| ORD | ORD | 1 | 275 |
| LAX | LAX | 1 | 50 |
| JFK | DFW, JFK | 2 | 525 |
| LAX | DFW, LAX | 2 | 500 |
| ORD | DFW, ORD | 2 | 400 |
| DFW | LAX, DFW | 2 | 250 |
| DFW | ORD, DFW | 2 | 375 |
| JFK | ORD, JFK | 2 | 525 |
| DFW | DFW, LAX, DFW | 3 | 700 |
| DFW | DFW, ORD, DFW | 3 | 500 |
| JFK | DFW, ORD, JFK | 3 | 650 |
| LAX | LAX, DFW, LAX | 3 | 450 |
| JFK | LAX, DFW, JFK | 3 | 475 |
| ORD | LAX, DFW, ORD | 3 | 350 |
| LAX | ORD, DFW, LAX | 3 | 575 |
| JFK | ORD, DFW, JFK | 3 | 600 |
| ORD | ORD, DFW, ORD | 3 | 475 |

Final result

| route | totalcost |
|---|---|
| LAX, DFW, JFK | 475 |

# Recursive Search

- *Only change the final query slightly, the least transfer time routes can be found :*

```
… …
SELECT route,  totalcost                                    --- final query
FROM trips
WHERE destination='JFK'  AND nsegs=                         --- least stop rule
                         (SELECT min(nsegs)
                          FROM trips
                          WHERE destination='JFK') ;
```

Final result

| route | totalcost |
|---|---|
| DFW, JFK | 525 |
| ORD, JFK | 525 |

# Data Manipulation Language

- Insert
  - Insert a tuple into a table
    - *INSERT INTO EMPLOYEES VALUES ('Smith', 'John', '1980-06-10', 'Los Angles', 16, 45000);*
- Delete
  - Delete tuples fulfill qualifications
    - *DELETE FROM Person WHERE LastName = 'Rasmussen' ;*
- Update
  - Update the attributes' value of tuples fulfill qualifications
    - *UPDATE Person SET Address = 'Zhongshan 23', City = 'Nanjing' WHERE LastName = 'Wilson';*

# View in SQL

- General view
  - Virtual tables derived from base tables
  - Logical data independence
  - Security of data
  - Update problems of view
- Temporary view and recursive query
  - WITH
  - RECURSIVE

# Update problems of view

- CREATE VIEW YoungSailor AS

  SELECT sid, sname, rating

  FROM Sailors

  WHERE age<26;

- CREATE VIEW Ratingavg AS

  SELECT rating, AVG(age)

  FROM Sailors

  GROUP BY rating;

# View in SQL

- General view
  - Virtual tables derived from base tables
  - Logical data independence
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  - Update problems of view
- Temporary view and recursive query
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# Update problems of view

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```
SELECT sid, sname, rating
FROM Sailors
WHERE age<26;
```

- CREATE VIEW Ratingavg AS

```
SELECT rating, AVG(age)
FROM Sailors
GROUP BY rating;
```

# Embedded SQL

- In order to access database in programs, and take further process to the query results, need to combine SQL and programming language (such as C / C++, etc.)
- Problems should be solved:
  - How to accept SQL statements in programming language
  - How to exchange data and messages between programming language and DBMS
  - The query result of DBMS is a set, how to transfer it to the variables in programming language
  - The data type of DBMS and programming language may not the same exactly.

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  - The data type of DBMS and programming language may not the same exactly.

# General Solutions

- Embedded SQL
  - The most basic method. Through pre-compiling, transfer the embedded SQL statements to inner library functions call to access database.
- Programming APIs
  - Offer a set of library functions or DLLs to programmer directly, linking with application program while compiling.
- Class Library
  - Supported after emerging of OOP. Envelope the library functions to access database as a set of class, offering easier way to treat database in programming language.

# Usage of Embedded SQL (in C)

- SQL statements can be used in C program directly:
  - Begin with *EXEC SQL*, end with ';'
  - Through *host variables* to transfer information between C and SQL. Host variables should be defined begin with *EXEC SQL*.
  - In SQL statements, should add ':' before host variables to distinguish with SQL's own variable or attributes' name.
  - In host language (such as C), host variables are used as general variables.
  - Can't define host variables as Array or Structure.
  - A special host variable, SQLCA (SQL Communication Area)
    EXEC SQL INCLUDE SQLCA
  - Use SQLCA.SQLCODE to justify the state of result.
  - Use *indicator* (short int) to treat *NULL* in host language.

# Example of *host variables* defining

```
EXEC SQL BEGIN DECLARE SECTION;
    char SNO[7];
    char GIVENSNO[7];
    char CNO[6];
    char GIVENCNO[6];
    float GRADE;
    short GRADEI;        /*indicator of GRADE*/
EXEC SQL END DECLARE SECTION;
```

# Executable Statements

- CONNECT
  - EXEC SQL CONNECT :uid IDENTIFIED BY :pwd;
- Execute DDL or DML Statements
  - EXEC SQL INSERT INTO SC(SNO,CNO,GRADE)
    VALUES(:SNO, :CNO, :GRADE);
- Execute Query Statements
  - EXEC SQL SELECT GRADE
    INTO :GRADE :GRADEI
    FROM SC
    WHERE SNO=:GIVENSNO AND
    CNO=:GIVENCNO;
- Because {SNO,CNO} is the key of SC, the result of this query has only one tuple. How to treat result if it has a set of tuples?

# Cursor

1. Define a cursor
   - EXEC SQL DECLARE <*cursor name*> CURSOR FOR
     SELECT …
     FROM …
     WHERE …
2. EXEC SQL OPEN <*cursor name*>
   - Some like open a file
3. Fetch data from cursor
   - EXEC SQL FETCH <*cursor name*>
     INTO :hostvar1, :hostvar2, …;
4. SQLCA.SQLCODE will return 100 when arriving the end of cursor
5. CLOSE CURSOR <*cursor name*>

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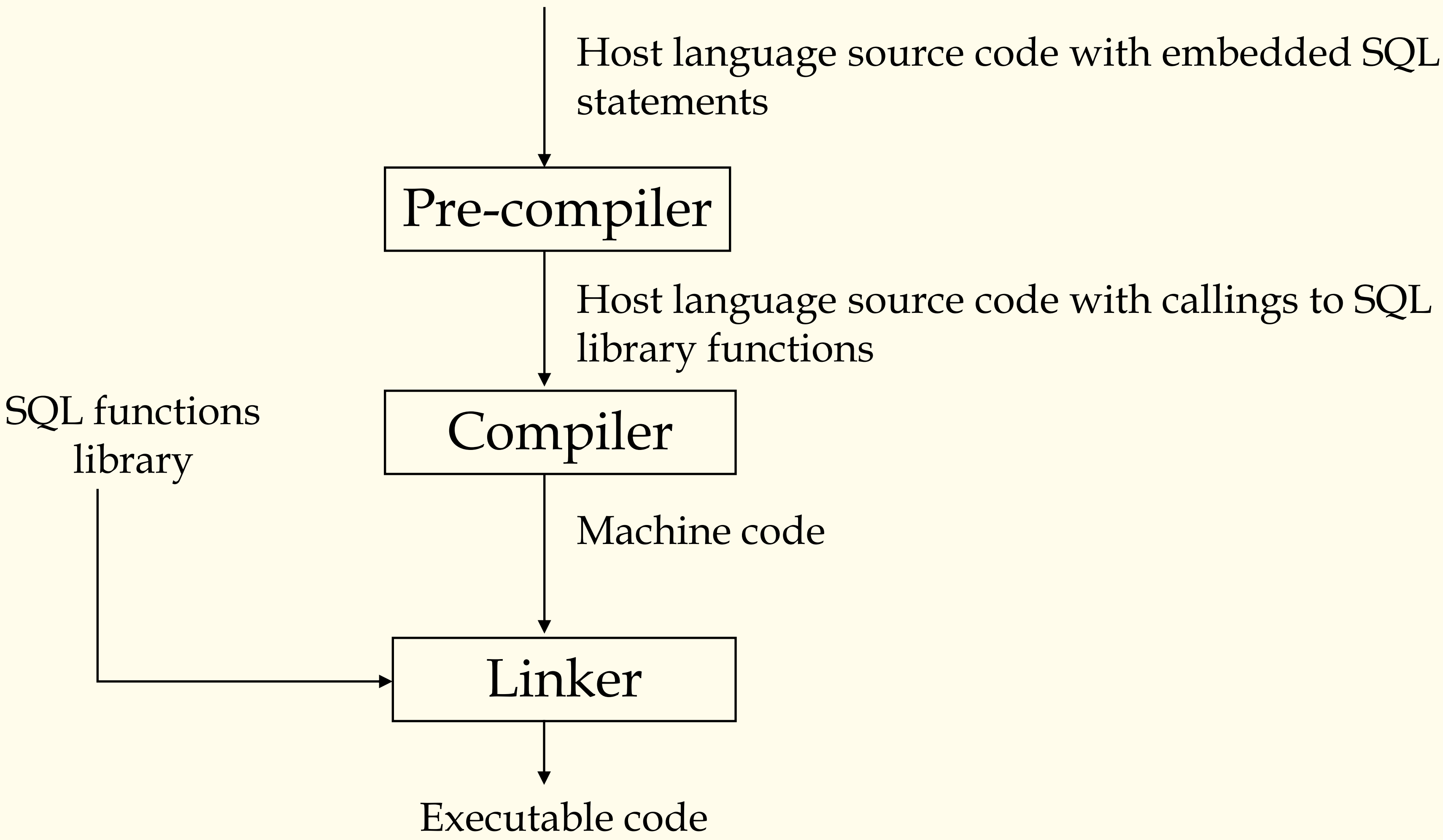
4. SQLCA.SQLCODE will return 100 when arriving the end of cursor
5. CLOSE CURSOR <*cursor name*>

# Example of Query with Cursor

```
            :
EXEC SQL DECLARE C1 CURSOR FOR
          SELECT SNO, GRADE
          FROM SC
          WHERE CNO = :GIVENCNO;
EXEC SQL OPEN C1;
if (SQLCA.SQLCODE<0) exit(1);        /* There is error in query*/
while (1) {
    EXEC SQL FETCH C1 INTO :SNO, :GRADE :GRADEI
    if (SQLCA.SQLCODE==100) break;
    /* treat data fetched from cursor, omitted*/
            :
}
EXEC SQL CLOSE C1;
            :
```

# Conceptual Evaluation



# Dynamic SQL

- In above embedded SQL, the SQL statements must be written before compiling. But in some applications, the SQL statement can't decided in ahead, they need to be built dynamically while the program running.
- Dynamic SQL is supported in SQL standard and most RDBMS pruducts
  - Dynamic SQL executed directly
  - Dynamic SQL with dynamic parameters
  - Dynamic SQL for query

# Dynamic SQL executed directly

- Only used in the execution of non query SQL statements

```
        :
EXEC SQL BEGIN DECLARE SECTION;
char sqlstring[200];
EXEC SQL END DECLARE SECTION;
char cond[150];
strcpy( sqlstring, "DELETE FROM STUDENT WHERE ");
printf(" Enter search condition :");
scanf("%s", cond);
strcat( sqlstring, cond);
EXEC SQL EXECUTE IMMEDIATE :sqlstring;
        :
```

# Dynamic SQL with dynamic parameters

- Only used in the execution of non query SQL statements. Use ***place holder*** to realize dynamic parameter in SQL statement. Some like the macro processing method in C.

```
        :
EXEC SQL BEGIN DECLARE SECTION;
char sqlstring[200];
int birth_year;
EXEC SQL END DECLARE SECTION;
strcpy( sqlstring, "DELETE FROM STUDENT WHERE
                   YEAR(BDATE) <= :y; ");
printf(" Enter birth year for delete :");
scanf("%d", &birth_year);
EXEC SQL PREPARE purge FROM :sqlstring;
EXEC SQL EXECUTE purge USING :birth_year;
        :
```

# Dynamic SQL with dynamic parameters

- Only used in the execution of non query SQL statements. Use ***place holder*** to realize dynamic parameter in SQL statement. Some like the macro processing method in C.

```
        :
EXEC SQL BEGIN DECLARE SECTION;
char sqlstring[200];
int birth_year;
EXEC SQL END DECLARE SECTION;
strcpy( sqlstring, "DELETE FROM STUDENT WHERE
                    YEAR(BDATE) <= :y; ");
printf(" Enter birth year for delete :");
scanf("%d", &birth_year);
EXEC SQL PREPARE purge FROM :sqlstring;
EXEC SQL EXECUTE purge USING :birth_year;
        :
```

# Dynamic SQL for query

- Used to form query statement dynamically

```
        :
EXEC SQL BEGIN DECLARE SECTION;
char sqlstring[200];
char SNO[7];
float GRADE;
short GRADEI;
char GIVENCNO[6];
EXEC SQL END DECLARE SECTION;
char orderby[150];
strcpy( sqlstring, "SELECT SNO,GRADE FROM SC WHERE CNO= :c ");
printf(" Enter the ORDER BY clause :");
scanf("%s", orderby);
strcat( sqlstring, orderby);
printf(" Enter the course number :");
scanf("%s", GIVENCNO);
EXEC SQL PREPARE query FROM :sqlstring;
EXEC SQL DECLARE grade_cursor CURSOR FOR query;
EXEC SQL OPEN grade_cursor USING :GIVENCNO;
```

# Dynamic SQL for query (Cont.)

```
if (SQLCA.SQLCODE<0) exit(1);                    /* There is error in query*/
while (1) {
    EXEC SQL FETCH grade_cursor INTO :SNO, :GRADE :GRADEI
    if (SQLCA.SQLCODE==100)     break;
    /* treat data fetched from cursor, omitted*/
            :
}
EXEC SQL CLOSE grade_cursor;
            :
```

# Stored Procedure

- Used to improve performance and facilitate users. With it, user can take frequently used database access program as a procedure, and store it in the database after compiling, then call it directly while need.
  - Make user convenient. User can call them directly and don't need code again. They are reusable.
  - Improve performance. The stored procedures have been compiled, so they don't need parsing and query optimization again while being used.
  - Expand function of DBMS. (can write script)

# Example of a Stored Procedure

```
EXEC SQL
    CREATE PROCEDURE drop_student
           (IN student_no CHAR(7),
            OUT message CHAR(30))
    BEGIN ATOMIC
           DELETE FROM STUDENT
                          WHERE SNO=student_no;
           DELETE FROM SC
                          WHERE SNO=student_no;
           SET message=student_no || 'droped';
    END;
EXEC SQL

            :
CALL drop_student(…);          /* call this stored procedure later*/
            :
```