UNIT 6

Structured Query Language (SQL)

Text: Chapter 5

Learning Goals

Given a database (a set of tables) you will be able to

- express a query in SQL, involving set operators, subqueries and aggregations
- rewrite SQL queries in one style (with one set of operators) with queries in a different style (using another set of operators)
- show that two SQL queries (with or without null values) are/aren't equivalent
- translate RA (or Datalog) queries to SQL queries and vice versa
- write SQL statements to insert, delete, update the database and define views
- write SQL statements to set certain constraints
- (in the project) use JDBC and Java to design DB transactions for the database users

Outline

- Data Definition Language
- Basic Structure
- Set Operations
- Aggregate Functions
- Null Values
- Nested Subqueries
- Modification of the Database
- Views
- Integrity Constraints
- Embedded SQL, JDBC

The SQL Query Language

- Developed by IBM (System R) in the 1970s
- Often pronounced as SEQUEL!
- Need for a standard since relational queries are used by many vendors
- Standards:
  - SQL-86
  - SQL-89 (minor revision)
  - SQL-92 (major revision, current standard)
  - SQL-99 (major extensions)
- Consists of several parts:
  - Data Definition Language (DDL)
  - Data Manipulation Language (DML)
    - Data Query
    - Data Modification

Creating Tables in SQL(DDL)

- A SQL relation schema is defined using the **create table** command:

  create table *r* (A_1 D_1, A_2 D_2, ..., A_n D_n,
  (integrity-constraint$_1$),
  ...,
  (integrity-constraint$_k$))

- *Integrity constraints (ICs) can be:*
  - *primary and candidate keys*
  - *foreign keys*
  - *general assertions*
    - **e.g., check** (grade **between** 0 **and** 100)

- Example:

```
CREATE TABLE Student
    (cid      CHAR(20) not null,
     name     CHAR(20),
     address  CHAR(20),
     phone    CHAR(8),
     major    CHAR(4),
     primary key (cid))
```

Domain Types in SQL

- **char(n).** Fixed length character string with length *n.*
- **varchar(n).** Variable length character strings, with maximum length *n.*
- **int.** Integer (machine-dependent).
- **smallint.** Small integer (machine-dependent).
- **numeric(p,d).** Fixed point number, with user-specified precision of *p* digits, with *d* digits to the right of decimal point.
- **real, double precision.** Floating point and double-precision floating point numbers, with machine-dependent precision.
- **float(n).** Floating point number, with user-specified precision of at least *n* digits.

- Null values are allowed in all the domain types.
  To preclude null values declare attribute to be **not null**
- **create domain** in SQL-92 and 99 creates user-defined domain types

e.g., create domain *person-name* **char**(20) **not null**

Date/Time Types in SQL

- **date.** Dates, containing a (4 digit) year, month and date
  - E.g. **date** '2001-7-27'
- **time.** Time of day, in hours, minutes and seconds.
  - E.g. **time** '09:00:30' **time** '09:00:30.75'
- **timestamp**: date plus time of day
  - E.g. **timestamp** '2001-7-27 09:00:30.75'
- **Interval**: period of time
  - E.g. Interval '1' day
  - Subtracting a date/time/timestamp value from another gives an interval value
  - Interval values can be added to date/time/timestamp values
- Relational DBMS offer a variety of functions to
  - extract values of individual fields from date/time/timestamp
  - convert strings to dates and vice versa
  - For instance in Oracle (date is a timestamp):
    - TO_CHAR(date, format)
    - TO_DATE(string, format)
    - format looks like: 'DD-Mon-YY HH:MI.SS'

Running Examples

Customer Database

- **Customer**(*cid*: integer, *cname*: string, *rating*: integer, *salary*: real)
- **Item**(*iid*: integer, *iname*: string, *type*: string)
- **Order**(*cid*: integer, *iid*: integer, *day*:date, *qty*:real)

Student Database

- **Student** (*sid*, *name*, *address*, *phone*, *major*)
- **Course** (*dept*, *cno*, *title*, *credits*)
- **Instructor**(*iname*, *degree*)
- **Section** (*dept*, *cno*, *secno*, *term*, *ins_name*)
- **Enrolled** (*sid*, *dept*, *cno*, *secno*, *term*, *mark*)
- **Prerequisite** (*dept*, *cno*, *pre_dept*, *pre_cno*)

Basic SQL Query

- SQL is based on set and relational operations with certain modifications and enhancements
- A typical SQL query has the form:

  select [distinct] $A_1, A_2, ..., A_n$
  from $r_1, r_2, ..., r_m$
  where P

  - A_is represent attributes
  - r_is represent relations
  - P is a predicate.

RA's projection

RA's selection

RA's join is done explicitly in P

- This query is nearly equivalent to the relational algebra expression.

$$\Pi_{A1, A2, ..., An}(\sigma_P (r_1 \times r_2 \times ... \times r_m))$$

- The result of a SQL query is a table (relation).
- If **distinct** is used, duplicates are eliminated. By default duplicates are *not* eliminated!

Dup-elim is expensive. How would you implement it?

Basic SQL Query

- Called *conjunctive query.*
- Equivalent RA expression involves select, project, and join.
- So, also called SPJ query.
- SPJ/conjunctive queries correspond in Datalog to:

$$p(\vec{X}) \leftarrow r_1(\vec{Y}), \ldots, r_k(\vec{Z}), V_i\, op\, U_j, \ldots, V_\ell\ op\ c, \ldots$$

- Union of SPJ queries (i.e., SPJU) queries => set of Datalog rules with the same head $p(\vec{X})$.
- SPJ with aggregation => SPJA queries; no counterpart in (pure datalog), although researchers have extended Datalog with aggregation (we won't cover this).

Conceptual Evaluation Strategy

- Typical SQL query:

```
SELECT    [DISTINCT] attr-list
FROM      relation-list
WHERE     qualification
```

- Semantics of a SQL query defined in terms of the following conceptual evaluation strategy (in order):
  - Compute the cross-product of *relation-list*.
  - Discard any resulting tuples that fail *qualifications*.
  - Drop attributes that are not in *attr-list*.
  - **If** DISTINCT is specified, eliminate duplicate rows.
- This strategy is not a super efficient way to compute a query! An optimizer will find more efficient strategies to compute *the same answers*.

Example Instances

- We will use these instances of the Customer, Item and Order relations in our examples.

Customer

cid	cname	rating	salary
40	J. Justin	7	70
35	G. Grumpy	8	90
50	R. Rusty	10	80

Item

iid	iname	type
100	Inspiron6400	laptop
102	LatituteD520	laptop
105	DimensionE520	desktop
110	CanonMP830	printer

Order

cid	iid	day	qty
40	102	10/10/06	2
50	105	11/12/06	5

Example of Conceptual Evaluation

SELECT cname
FROM Customer, Order
WHERE Customer.cid=Order.cid AND iid=105

Customer X Order

(cid)	cname	rating	salary	(cid)	iid	day	qty
40	J. Justin	7	70	40	102	10/10/06	2
40	J. Justin	7	70	50	105	11/12/06	5
35	G. Grumpy	8	90	40	102	10/10/06	2
35	G. Grumpy	8	90	50	105	11/12/06	5
50	R. Rusty	10	80	40	102	10/10/06	2
50	R. Rusty	10	80	**50**	105	11/12/06	5

Renaming Attributes in Result

- SQL allows renaming relations and attributes using the **as** clause:

  old-name **as** *new-name*

- Example: Find the name of customers who have ordered item 105 and the day they placed the order; rename cname to "customer_name":

```
SELECT  cname AS customer_name, day
FROM    Customer, Order
WHERE   Customer.cid=Order.cid AND iid=105
```

Range Variables

- We can use variables to name relations in the FROM clause
  - Usually used when same relation appears twice.
- The previous query can also be written as:

```
SELECT  cname, day
FROM    Customer C, Order R
WHERE   C.cid=R.cid AND iid=105
```

OR

```
SELECT  C.cname, R.day
FROM    Customer C, Order R
WHERE   C.cid=R.cid AND R.iid=105
```

Nothing but

$$ans(N, D) \leftarrow customer(I, N, R, S), order(I, `105', D, Q).$$

Using DISTINCT

- Find customers (id's) who've ordered at least one item :

```
SELECT  C.cid
FROM    Customer C, Order R
WHERE   C.cid=R.cid
```

- Would adding DISTINCT to this query make a difference?
- Suppose we replace *C.cid* by *C.cname* in the SELECT clause. Would adding DISTINCT to this variant of the query make a difference?
- What if we use * in SELECT (* selects whole tuples)?

```
SELECT  *
FROM    Customer C, Order R
WHERE   C.cid=R.cid
```

Expressions and Strings

```
SELECT  C.salary, tax=(C.salary-10)*0.3, C.salary*0.01 AS prof_ fees
FROM    Customer C
WHERE   C.cname LIKE 'B_%B'
```

- Illustrates use of arithmetic expressions and string pattern matching:
  Returns triples of values, each consisting of
  the salary
  the income tax deducted (30% of salary minus 10K) and
  the professional fees (1% of the salary)
  for customers whose names begin and end with B and contain at least three characters.
- AS and = are two ways to name fields in result.

More on Strings

- LIKE is used for string matching:
  - `_' stands for any one character and
  - `%' stands for 0 or more arbitrary characters.
- To match the name "Strange%", need to use an escape character:

  like 'Strange\%' **escape** '\'
- SQL supports a variety of string operations such as
  - concatenation (using "||")
  - converting from upper to lower case (and vice versa)
  - finding string length, extracting substrings, etc.

Ordering of Tuples

- List in alphabetic order the names of the customers who have ordered a laptop

  select *cname*
  from *Customer, Item, Order*
  where *Customer.cid = Order.cid* **and**
  Item.iid= Order.iid ***and*** *type='laptop'*
  order by *cname*

- Order is specified by:

  Ordering goes beyond RA and Datalog!

  - **desc** for descending order or
  - **asc** for ascending order; ascending order is the default.
  - E.g., **order by** *cname* **desc**

Set Operations

- **union**, **intersect**, and **except** operate on tables (relations) and correspond to the RA operations $\cup, \cap, -$.
- Each of the above operations automatically eliminates duplicates;
  To retain all duplicates use the corresponding multiset versions:

  union all, **intersect all** and **except all**.
- Suppose a tuple occurs *m* times in *r* and *n* times in *s*, then, it occurs:
  - $m + n$ times in *r* **union all** *s*
  - $\min(m,n)$ times in *r* **intersect all** *s*
  - $\max(0, m - n)$ times in *r* **except all** *s*

Set Operations : UNION

What do we get If we replace OR by AND here ?

- **Example:** ***Find cid's of customers who've ordered a laptop or a desktop***

```
SELECT  C.cid
FROM  Customer C, Item I, Order R
WHERE  C.cid=R.cid AND R.iid=I.iid  AND (I.type='laptop' OR
   I.type='desktop')
```

- **UNION** can be used to compute the union of any two *compatible* (corresponding attributes have same domains) sets of tuples (which are themselves the result of SQL queries):

```
SELECT  C.cid
FROM  Customer C, Item I, Order R
WHERE  C.cid=R.cid AND R.iid=I.iid  AND I.type='laptop'
UNION
SELECT  C.cid
FROM  Customer C, Item I, Order R
WHERE  C.cid=R.cid AND R.iid=I.iid AND I.type='desktop'
```

Set Operations : EXCEPT

- **EXCEPT** can be used to compute the difference of two *compatible* sets of tuples
- Some systems use **MINUS** instead of EXCEPT
- What does the following query return?

```
SELECT  C.cid
FROM  Customer C, Item I, Order R
WHERE  C.cid=R.cid AND R.iid=I.iid  AND I.type='laptop'
EXCEPT
SELECT  C.cid
FROM  Customer C, Item I, Order R
WHERE  C.cid=R.cid AND R.iid=I.iid AND I.type='desktop'
```

What does EXCEPT remind you of in Datalog?

Set Operations: INTERSECT

- **Example:** Find cid's of customers who've ordered a laptop <u>and</u> a desktop item :

```
SELECT  C.cid
FROM  Customer C, Item I1, Order R1, Item I2, Order R2
WHERE  C.cid=R1.cid AND R1.iid=I1.iid
     AND  C.cid=R2.cid AND R2.iid=I2.iid
     AND  I1.type='laptop' AND I2.type='desktop')
```

- **INTERSECT c**an be used to compute the intersection of two *compatible* sets of tuples (included in SQL/92, but some systems may not support it).

```
SELECT  C.cid
FROM  Customer C, Item I, Order R
WHERE  C.cid=R.cid AND R.iid=I.iid  AND I.type='laptop'
INTERSECT
SELECT  S.cid
FROM  Customer S, Item I, Order R
WHERE  C.cid=R.cid AND R.iid=I.iid  AND I.type='desktop'
```

Important to include the Key!

Nested Queries

Find names of customers who've ordered item #105:

```
SELECT  C.cname
FROM  Customer C
WHERE  C.cid IN  (SELECT  R.cid
                  FROM  Order R
                  WHERE  iid=105)
```

- A very powerful feature of SQL:
  a **WHERE** clause can itself contain a SQL query! (Actually, so can FROM and HAVING clauses.)
- To find customers who've *not* ordered item #105, use **NOT IN**.
- To understand semantics of nested queries, think of a *nested loops* evaluation:
  - *For each Customer tuple, check the qualification by computing the subquery.*

Nested Queries with Correlation

Find names of customers who've ordered item #105:

```
SELECT  C.cname
FROM  Customer C
WHERE  EXISTS  (SELECT  *
                FROM  Order R
                WHERE  iid=105 AND C.cid=R.cid)
```

- **EXISTS** is another set operator: *returns true if the set is not empty*.
- **UNIQUE** checks for duplicate tuples: *returns true if there are no duplicates*.
- If **UNIQUE** is used above, and * is replaced by *iid*, finds customers with at most one order for item #105.
  - (* denotes all attributes. Why do we have to replace * by *iid*?)
- Ilustrates why, in general, subquery must be re-computed for each Customer tuple.

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**,
  where op is one of: >, <, =, <=, >=, <>
- Find customers whose salary is greater than that of every customer with last name "Rusty":

```
SELECT *
FROM Customer C
WHERE C.salary > ALL (SELECT C2.salary
                      FROM Customer C2
                      WHERE C2.cname LIKE '% Rusty')
```

How did we write such queries in RA?
How about Datalog?

3a

Rewriting INTERSECT Queries Using IN

Find cid's of customers who've ordered both a laptop and a desktop:

```
SELECT  C.cid
FROM  Customer C, Item I, Order R
WHERE  C.cid=R.cid AND R.iid=I.iid AND I.type='laptop'
       AND C.cid IN  (SELECT  C2.cid
                      FROM  Customer C2, Item I2, Order R2
                      WHERE  C2.cid=R2.cid AND R2.iid=I2.iid
                             AND  I2.type='desktop')
```

- Similarly, EXCEPT queries can be re-written using NOT IN.
- To find *names* (not *cids*) of customers who've ordered both laptops and desktops, just replace *C.cid* by *C.cname* in SELECT clause. Could we replace cid by cname throughout? (What about INTERSECT query?)

Division in SQL

Find customers who've ordered all items.

Let's do it the hard way without EXCEPT:

(1)
```
SELECT  cname
FROM    Customer C
WHERE  NOT EXISTS  (SELECT  *
                    FROM  Item I
                    WHERE  NOT EXISTS  (SELECT  *
                                        FROM  Order R
                                        WHERE  R.iid=I.iid
                                            AND R.cid=C.cid))
```

select customer C such that ...

there is no item I…

which is not ordered by C

(2)
```
SELECT  cname
FROM    Customer C
WHERE  NOT EXISTS
         ((SELECT  I.iid
           FROM  Item I)
          EXCEPT
           (SELECT  R.iid
            FROM  Order R
            WHERE  R.cid=C.cid))
```

How does it compare with RA/Datalog?

Aggregate Operators

- These functions operate on the multiset of values of a column of a relation, and return a value

  AVG: average value
  MIN: minimum value
  MAX: maximum value
  SUM: sum of values
  COUNT: number of values

- The following versions eliminate duplicates before apply the operation to attribute *A*:

  COUNT (DISTINCT A)
  SUM (DISTINCT A)
  AVG (DISTINCT A)

Aggregate Operators: Examples

```
SELECT  COUNT (*)
FROM    Customer
```

```
SELECT  cname
FROM    Customer C
WHERE   C.rating= (SELECT  MAX(C2.rating)
                   FROM  Customer C2)
```

```
SELECT  AVG (salary)
FROM    Customer
WHERE   rating=10
```

```
SELECT  AVG ( DISTINCT salary)
FROM    Customer
WHERE   rating=10
```

```
SELECT  COUNT (DISTINCT rating)
FROM    Customer
WHERE   salary BETWEEN 50 AND 100
```

Aggregate Operators: Examples(cont)

Find name and salary of the richest customer(s)

- The first query is wrong! WHY?

```
SELECT  cname, MAX (salary)
FROM    Customer
```

- Second query is fine: can use
  value = subquery
  only if subquery returns single value.

```
SELECT  cname, salary
FROM    Customer
WHERE   salary =
        (SELECT  MAX (salary)
         FROM  Customer)
```

- 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  cname, salary
FROM    Customer
WHERE   (SELECT  MAX (salary)
         FROM  Customer)
        = salary
```

GROUP BY and HAVING

- Often, we want to divide tuples into groups and apply aggregate operations to each group.
- Example: *Find the average salary of the customers in each rating level.*
  - 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  AVG (salary)
FROM    Customer
WHERE   rating = i
```

- Problem:
  - We don't know how many rating levels exist, and what the rating values for these levels are!
- Solution:
  - Use "GROUP BY" and/or "HAVING" clauses

GROUP BY and HAVING (cont)

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

- The *target-list* contains
  (i) attribute names
  (ii) terms with aggregate operations (e.g., AVG (*salary*)).
- Attributes in (i) must also be in *grouping-list*.
  - each answer tuple corresponds to a *group*,
  - a *group* is a set of tuples that have the same value for all attributes in *grouping-list*
  - selected attributes in (i) must have a single value per group.
- Attributes in *group-qualification* are either in *grouping-list* or are arguments to an aggregate operator.

Conceptual Evaluation of a Query

1. compute the cross-product of *relation-list*
2. keep only tuples that satisfy *qualification*
3. partition selected tuples into groups by the value of attributes in *grouping-list*
4. keep only the groups that satisfy *group-qualification* (expressions in *group-qualification* must have a *single value per group*!)
5. keep only the fields that are in *target-list*
6. generate one answer tuple per qualifying group.

GROUP BY Example

- Example1: *For each item, find the salary of the poorest customer who has ordered this item:*

```
SELECT      iid,  MIN (salary)
FROM        Customer C, Order R
WHERE       C.cid= R.cid
GROUP BY    iid
```

GROUP BY Example: Default Evaluation

Customer

<u>cid</u>	cname	rating	salary
40	J. Justin	7	70
35	G. Grumpy	8	90
50	R. Rusty	10	80

Order

<u>cid</u>	<u>iid</u>	<u>day</u>	qty
40	102	10/10/06	2
50	105	11/12/06	5
40	102	25/06/07	3
35	102	30/06/07	5

$\sigma_{C.cid=R.cid}$ **(Customer X Order)**

(cid)	cname	rating	salary	(cid)	iid	day	qty
40	J. Justin	7	70	40	102	10/10/06	2
40	J. Justin	7	70	40	102	25/06/07	3
35	G. Grumpy	8	90	35	102	30/06/07	5
50	R. Rusty	10	80	50	105	11/12/06	5

GROUP BY Example (cont')

$\sigma_{C.cid=R.cid}$ **(Customer X Order) and grouped by iid**

(cid)	cname	rating	salary	(cid)	iid	day	qty
40	J. Justin	7	70	40	102	10/10/06	2
40	J. Justin	7	70	40	102	25/06/07	3
35	G. Grumpy	8	90	35	102	30/06/07	5
50	R. Rusty	10	80	50	105	11/12/06	5

Result

iid	Min(salary)
102	70
105	80

GROUP BY and HAVING Example

- Example2: *For each item that has more than 2 orders, find the salary of the poorest customer who has ordered this item:*

```
SELECT    iid, MIN (salary)
FROM      Customer C, Order R
WHERE     C.cid= R.cid
GROUP BY  iid
HAVING    COUNT (*) > 2
```

Grouping Examples (contd.)

For each laptop item, find the number of (distinct) customers who ordered this item

```
SELECT   I.iid,  COUNT (DISTINCT R.cid) AS scount
FROM     Item I, Order R
WHERE    R.iid=I.iid AND I.type='laptop'
GROUP BY I.iid
```

- Grouping over a join of two relations.
- What do we get if we:
  (a) remove *I.type='laptop'* from the WHERE clause, and then
  (b) add a HAVING clause with this dropped condition?
- What if we replace

  COUNT (DISTINCT R.cid)

  with

  COUNT (*) ?

More Grouping Examples

For each rating that has at least 2 customers whose salary is at least 50K, find the average salary of these customers for that rating

```
SELECT     rating,  AVG (salary)
FROM       Customer
WHERE      salary >= 50
GROUP BY   rating
HAVING     COUNT (*) > 1
```

- Only rating can appear alone in the SELECT and/or HAVING clauses.
- 2nd column of result is unnamed. (Use AS to name it.)

Customer

cid	cname	rating	salary
22	J. Justin	7	50
31	R. Rubber	8	55
71	Z. Zorba	~~10~~	~~16~~
64	H. Hasty	7	80
29	B. Brutus	1	50
58	R. Rusty	10	100

rating	salary
7	50
8	55
7	80
1	50
10	100

rating	
7	65

Answer relation

Grouping Examples (cont')

For each rating that has at least 2 customers (of any salary), find the average salary among the customers with that rating whose salary is at least 50K.

```
SELECT   C.rating,  AVG (C.salary)
FROM     Customer C
WHERE    C.salary >= 50
GROUP BY C.rating
HAVING   1  <  (SELECT  COUNT (*)
                FROM  Customer C2
                WHERE  C2.rating=C.rating)
```

- Shows HAVING clause can also contain a subquery.
- Compare this with the query where we concidered only ratings with at least 2 customers with salary at least 50K!
- What if HAVING clause is replaced by:
  - HAVING COUNT(*) >1

Grouping Examples (contd.)

Find those ratings for which their average salary is the minimum over all ratings

```
SELECT  C.rating
FROM    Customer C
WHERE   C.salary =  (SELECT  MIN (AVG (C2.salary))  FROM Customer C2)
```

- WRONG! Aggregate operations cannot be nested!
- Correct solution (in SQL/92 and SQL/99)

```
SELECT  Temp.rating, Temp.avgsalary
FROM    (SELECT  C.rating, AVG (C.salary) AS avgsalary
         FROM  Customer C
         GROUP BY  C.rating) AS  Temp
WHERE  Temp.avgsalary = (SELECT  MIN (Temp.avgsalary)
                         FROM  Temp)
```

Null Values

- Tuples may have a null value, denoted by *null*, for some of their attributes
- Value *null* signifies an unknown value or that a value does not exist.
- The predicate **IS NULL** (**IS NOT NULL**) can be used to check for null values.
  - E.g., *Find the names of the customers whose salary is not known.*

```
SELECT cname
FROM Customer
WHERE salary IS NULL
```

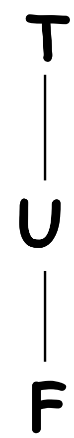
- The result of any arithmetic expression involving *null* is *null*
  - E.g., 5 + *null* returns *null.*

Null Values and Three-Valued Logic

- To deal with null values we need a three-valued logic using the truth value *unknown*:

OR	False	Unknown	True
False	F	U	T
Unknown	U	U	T
True	T	T	T

Classical Logic is 2-valued.



Lattice of truth values in Kleene's 3-valued logic.

Null Values and Three-Valued Logic

- To deal with null values we need a three-valued logic using the truth value *unknown*:

AND	False	Unknown	True
False	F	F	F
Unknown	F	U	U
True	F	U	T

Classical Logic is 2-valued.

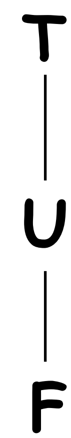
T
|
U
|
F

Lattice of truth values in Kleene's 3-valued logic.

Null Values and Three-Valued Logic

- To deal with null values we need a three-valued logic using the truth value *unknown*:

	False	Unknown	True
NOT	T	U	F



Classical Logic is 2-valued.

Lattice of truth values in Kleene's 3-valued logic.

Null Values and Three-Valued Logic

- In particular, note:
  - OR: (*unknown* **or** *true*) = *true*, (*unknown* **or** *false*) = *unknown*
    (*unknown* **or** *unknown*) = *unknown*
  - AND: *(true* **and** *unknown) = unknown, (false* **and** *unknown) = false,*
    (unknown **and** *unknown) = unknown*
  - NOT*: (***not** *unknown) = unknown*
  - "*P* **is unknown**" evaluates to true if predicate *P* evaluates to *unknown*
- Any comparison with *null* returns *unknown*
  - *E.g. 5 < null or null <> null or null = null*
- Result of **where** clause predicate is treated as *false* if predicate evaluates to *unknown*
- All aggregate operations except **count(*)** ignore tuples with null values on the aggregated attributes.

Summary of "impact" of null values

- Represent "unknown" or "inapplicable".
- Make arithmetic expressions evaluate to "unknown" (U).
- Make logical expressions evaluate to T, **U**, of F.
- SQL treats truth value U in where clause as F.
- SQL ignores tuples with nulls on aggregated attr when aggregating using any function save **Count**.
- SQL counts all tuples regardless of presence of nulls.
- SQL lets you test if a value is null via IS NULL and IS NOT NULL.

Database Modification – Insertion

- Can insert a single tuple using:

```
INSERT INTO Student
VALUES (53688, 'Smith', '222 W.15th ave', 333-4444, MATH)
```

- or

```
INSERT INTO Student (sid, name, address, phone, major)
VALUES (53688, 'Smith', '222 W.15th ave', 333-4444, MATH)
```

- Add a tuple to student with null address and phone:

```
INSERT INTO Student (sid, name, address, phone, major)
VALUES (33388, 'Chan', null, null, CPSC)
```

What if there was a "not null" constraint on address or phone?

Database Modification – Insertion (contd.)

- Can add values selected from another table?
- Add an order for customer 222 for every laptop item with date 1/1/07 and quantity 5
- INSERT INTO Order
  SELECT 222, iid, '1/1/07', 5
  FROM Item
  WHERE type ='laptop'

Query-driven insert.

- The **select-from-where statement** is fully evaluated before any of its results are inserted

  So, statements like

  INSERT INTO table1 SELECT ...... FROM table1

  are ok.

How would you say add orders for a specific item (iid) from every customer rated at 6 or above?

Database Modification – Deletion

- Note that only whole tuples are deleted.
- Can delete all tuples satisfying some condition (e.g., name = Smith):

```
DELETE FROM Student
WHERE name = 'Smith'
```

- Delete all Customers whose salary is above the average sailor salary:

```
DELETE FROM Customer
WHERE salary > (SELECT avg(salary)
                FROM Customer)
```

Do you see any problem with this?

Database Modification – Updates

- Increase the rating of all customers by 2 (should not be more than 10)
- Need to write two updates:

```
UPDATE  Customer
SET  rating = 10
WHERE rating >= 8

UPDATE  Customer
SET rating = rating + 2
WHERE rating < 8
```

- Is the order important?
- How would you raise by 10% the salary of every customer rated at 8 or above?

Views

- Provide a mechanism to hide certain data from certain users. To create a view we use the command:

  CREATE VIEW *vname* **AS** <query expression>

  where:

  - <query expression> is any legal SQL expression
  - *vname* is the view name

- Example:

```
CREATE VIEW LDOrder AS
SELECT cid, iid, type, date
FROM Item I, Order R
WHERE I.iid = R.iid AND (type = 'laptop' OR
                         type = 'desktop')
```

With Clause

- Allows views to be defined locally to a query, rather than globally.
- Example:

```
WITH   LDOrder(cid, iid, type, date)    AS
          SELECT cid, iid, type, date
          FROM Item I, Order R
          WHERE I.iid = R.iid AND (type = ‘laptop’ OR
                                   type = ‘desktop’)
SELECT cid, cname
FROM Customer C,  LDOrder R
WHERE C.cid = R.cid AND date > ‘1/1/07’
```

SQL's Join Operators

- Join operations take two relations and return as a result another relation.
- These additional operations are typically used as subquery expressions in the **from** clause
- Join condition – defines which tuples in the two relations match, and what attributes are present in the result of the join.
- Join type – defines how tuples in each relation that do not match any tuple in the other relation (based on the join condition) are treated.

Join Types
inner join **left outer join** **right outer join** **full outer join**

Join Conditions
natural **on** <predicate>

Example: SELECT S.name, E.dept, E.cno
FROM Student S NATURAL LEFT OUTER JOIN Enrolled E

Integrity Constraints (Review)

- An IC describes conditions that every *legal instance* of a relation must satisfy.
  - Inserts/deletes/updates that violate IC's are disallowed.
  - Can be used to ensure application semantics (e.g., *cid* is a key), or prevent inconsistencies (e.g., *cname* has to be a string, *salary* must be < 200)
- *Types of IC's*:
  - domain constraints,
  - primary key constraints,
  - foreign key constraints,
  - general constraints

General Constraints

- Create with a CHECK clause.
- Constraints can be named
- Can use subqueries to express constraint

```
CREATE TABLE  Order1
(         cid        INTEGER,
          iid        INTEGER,
          day        DATE,
          qty        REAL,
          PRIMARY KEY  (cid, iid, day),
          CHECK  (`Printer' <>
                        ( SELECT  I.type
                          FROM    Item I
                          WHERE  I.iid=iid)));
```

```
CREATE TABLE   Customer
     cid       INTEGER,
     cname   CHAR(10),
     rating   INTEGER,
     salary   REAL,
     PRIMARY KEY  (cid),
     CHECK  ( rating >= 1
              AND rating <= 10 );
```

Check constraints are checked when tuples are inserted or modified

Domain Constraints

- User can create a new domain and set constrains for it.
- Example:

  CREATE DOMAIN agedomain INTEGER

  DEFAULT 21

  CHECK (VALUE >= 1 AND VALUE <= 110)

-
-

Constraints Over Multiple Relations

- Cannot be defined in one table.
- Are defined as ASSERTIONs which are not associated with any one table.
- Example: *Every student has taken at least one course.*

```
CREATE ASSERTION totalEnrolment
CHECK
( NOT EXISTS ((SELECT sid FROM student)
                    EXCEPT
                   (SELECT sid FROM Enrolled)));
```

What would this IC look like in Datalog-like syntax?

Transactions

- A transaction is a sequence of queries and update statements executed as a single unit
  - Transactions are started implicitly and terminated by one of
    - **commit work:** makes all updates of the transaction permanent in the database
    - **rollback work:** undoes all updates performed by the transaction.
- Example
  - Transfer of money from account A to account B involves two steps:
    - deduct from A and add to B
  - If one step succeeds and the other fails, database is in an inconsistent state
  - Therefore, either both steps should succeed or neither should
- If any step of a transaction fails, all work done by the transaction can be undone by **rollback work.**
- Rollback of incomplete transactions is done automatically, in case of system failures

Transactions (Contd.)

- In most database systems, each SQL statement that executes successfully is automatically committed.
  - Each transaction consists of only a single statement
- Automatic commit can usually be turned off, but how to do so depends on the database system
- Another option in SQL:1999: enclose statements within

```
begin atomic
      …
  end
```

Summary

- SQL was an important factor in the early acceptance of the relational model; more natural than earlier, procedural query languages.
- Relationally complete; in fact, significantly more expressive power than relational algebra.
- Consists of a data definition, data manipulation and query language.
- Many alternative ways to write a query; optimizer looks for most efficient evaluation plan.
  - Holy Grail: users don't have to care about efficiency, and relegate finding an efficient plan to QOzer.
  - In practice, users need to be aware of how queries are optimized and evaluated for best results.

Summary (Contd.)

- NULL for unknown field values brings many complications
- SQL allows specification of rich integrity constraints (and triggers)
- Embedded SQL allows execution within a host language; cursor mechanism allows retrieval of one record at a time
- APIs such as ODBC and JDBC introduce a layer of abstraction between application and DBMS