IF3111 - SQL

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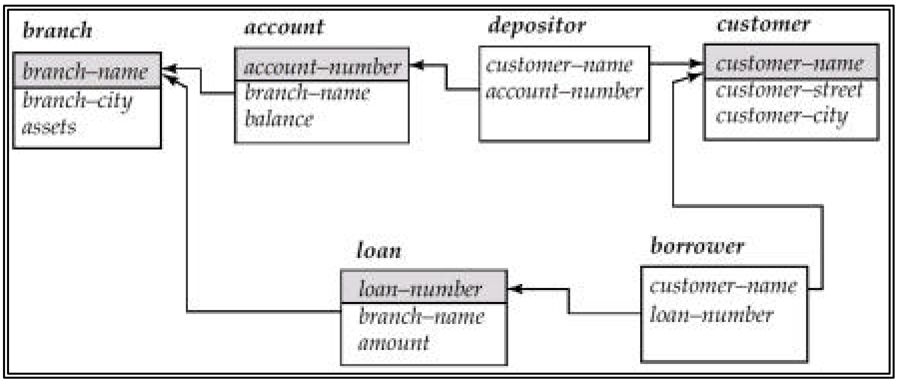
Schema Used in Examples



Basic Structure

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

  select $A_1, A_2, \ldots, A_n$
  from $r_1, r_2, \ldots, r_m$
  where P

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

  This query is equivalent to the relational algebra expression.

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

The result of a SQL query is a relation.

The SELECT Clause

- The **select** clause list the attributes desired in the result
  - corresponds to the projection operation of the relational algebra
- E.g. find the names of all branches in the *loan* relation

  select *branch-name*
  from *loan*
- In the “pure” relational algebra syntax:

  $\Pi_{\text{branch-name}}(\textit{loan})$
- SQL allows duplicates in both relations and query results.
  - To force the elimination of duplicates, use the keyword **distinct** after **select.**

    select distinct *branch-name*
    from *loan*
  - The keyword **all** specifies that duplicates not be removed (default).

    select all *branch-name*
    from *loan*

NOTE: SQL does not permit the ‘-’ character in names,

Use, e.g., *branch_name* instead of *branch-name* in a real implementation.

We use ‘-’ since it looks nicer!

The SELECT Clause (Cont.)

- An asterisk in the select clause denotes "all attributes"

  select *
  from *loan*

- The **select** clause can contain arithmetic expressions involving the operation, +, –, ∗, and /, and operating on constants or attributes of tuples.
- The query:

  select *loan-number, branch-name, amount* ∗ 100
  from *loan*

  would return a relation which is the same as the *loan* relations, except that the attribute *amount* is multiplied by 100.

The WHERE Clause

- The **where** clause specifies conditions that must be satisfied
  - corresponds to the selection predicate of the relational algebra.
- To find all loan number for loans made at the Perryridge branch with loan amounts greater than $1200.

  select *loan-number*
  from *loan*
  where *branch-name* = 'Perryridge' **and** *amount* > 1200
- Comparison results can be combined using the logical connectives **and, or,** and **not.**
- Comparisons can be applied to results of arithmetic expressions.
- SQL includes a **between** comparison operator
  - E.g. Find the loan number of those loans with loan amounts between $90,000 and $100,000 (that is, ≥$90,000 and ≤$100,000)

    select *loan-number*
    from *loan*
    where *amount* **between** *90000* **and** *100000*

The FROM Clause

- The **from** clause lists the relations involved in the query
  - corresponds to the Cartesian product operation of the relational algebra.
- Find the Cartesian product *borrower x loan*

  select *
  from *borrower, loan*
- Find the name, loan number and loan amount of all customers having a loan at the Perryridge branch.

The Rename Operation and Tuple Variables

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

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

  – Find the name, loan number and loan amount of all customers; rename the column name *loan-number* as *loan-id.*

  select *customer-name, borrower.loan-number* **as** *loan-id, amount*
  from *borrower, loan*
  where *borrower.loan-number = loan.loan-number*

- Tuple variables are defined in **from** clause via **as** clause.

  – Find the customer names and their loan numbers for all customers having a loan at some branch.

  select *customer-name, T.loan-number, S.amount*
  from *borrower* **as** *T, loan* **as** *S*
  where *T.loan-number = S.loan-number*

  – Find the names of all branches that have greater assets than some branch located in Brooklyn.

  select distinct *T.branch-name*
  from *branch* **as** *T, branch* **as** *S*
  where *T.assets > S.assets* **and** *S.branch-city* = 'Brooklyn'

String Operations

- SQL includes a string-matching operator for comparisons on character strings. Patterns are described using two special characters:
  - percent (%). The % character matches any substring.
  - underscore (_). The _ character matches any character.
- Find the names of all customers whose street includes the substring "Main".

  select *customer-name*
  from *customer*
  where *customer-street* **like '**%Main%'

- Match the name "Main%"

  like 'Main\%' **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 the Display of Tuples

- List in alphabetic order the names of all customers having a loan in Perryridge branch

  select distinct *customer-name*
  from *borrower, loan*
  where *borrower loan-number - loan.loan-number*
  and *branch-name* = 'Perryridge'
  order by *customer-name*

- We may specify **desc** for descending order or **asc** for ascending order, for each attribute; ascending order is the default.
  - E.g. **order by** *customer-name* **desc**

Duplicates

- In relations with duplicates, SQL can define how many copies of tuples appear in the result.
- *Multiset* versions of some of the relational algebra operators – given multiset relations r_1 and r_2:

1. **σ_q (r_1):** If there are c_1 copies of tuple t_1 in r_1, and t_1 satisfies selections σ_q, then there are c_1 copies of t_1 in $\sigma_q(r_1)$.
2. **$\Pi_A(r)$:** For each copy of tuple t_1 in r_1, there is a copy of tuple $\Pi_A(t_1)$ in $\Pi_A(r_1)$ where $\Pi_A(t_1)$ denotes the projection of the single tuple t_1.
3. **$r_1 \times r_2$:** If there are c_1 copies of tuple t_1 in r_1 and c_2 copies of tuple t_2 in r_2, there are $c_1 \times c_2$ copies of the tuple $t_1 . t_2$ in $r_1 \times r_2$

- SQL duplicate semantics:

select $A_1, A_2, \ldots, A_n$
from $r_1, r_2, \ldots, r_m$
where P

is equivalent to the *multiset* version of the expression:

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

Example:

Suppose multiset relations r_1 (A, B) and r_2 (C) are as follows:

$r_1 = \{(1, a)\ (2,a)\}$ $\quad r_2 = \{(2), (3), (3)\}$

Set Operations

- The set operations **union, intersect,** and **except** operate on relations and correspond to the relational algebra 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*
- Find all customers who have a loan, an account, or both.

  (**select** *customer-name* **from** *depositor*)
  union (**select** *customer-name* **from** *borrower)*
- Find all customers who have both a loan and an account.
- Find all customers who have an account but no loan.

Aggregate Functions

- 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

- Find the average account balance at the Perryridge branch.

  select avg *(balance)*
  from *account*
  where *branch-name* = 'Perryridge'

- Find the number of tuples in the *customer* relation.

  select count (*)
  from *customer*

- Find the number of depositors in the bank.

Aggregate Functions – Group By & Having

- Find the number of depositors for each branch.

```
select branch-name, count (distinct customer-name)
from depositor, account
where depositor.account-number = account.account-number
group by branch-name
```

- Find the names of all branches where the average account balance is more than $1,200.

```
select branch-name, avg (balance)
from account
group by branch-name
having avg (balance) > 1200
```


Attributes in **select** clause outside of aggregate functions must appear in **group by** list

Predicates in the **having** clause are applied after the formation of groups whereas predicates in the **where** clause are applied before forming groups

Null Values

- It is possible for tuples to have a null value, denoted by *null*, for some of their attributes
- *null* signifies an unknown value or that a value does not exist.
- The predicate **is null** can be used to check for null values.
  - E.g. Find all loan number with null values for *amount.*

    select *loan-number*
    from *loan*
    where *amount* **is null**
- The result of any arithmetic expression involving *null* is *null*
  - E.g. 5 + null returns null
- Aggregate functions simply ignore nulls
  - Total all loan amounts

    select sum (*amount)*
    from *loan*
    - Above statement ignores null amounts
    - result is null if there is no non-null amount, that is the
  - All aggregate operations except **count(*)** ignore tuples with null values on the aggregated attributes.

Null Values and Three Valued Logic

- Any comparison with *null* returns *unknown*
  - *E.g. 5 < null or null <> null or null = null*
- Three-valued logic using the truth value *unknown*:
  - OR: (*unknown* **or** *true*) = , (*unknown* **or** *false*) =
    (*unknown* **or** *unknown*) =
  - AND: *(true* **and** *unknown)* = , *(false* **and** *unknown)* = ,
    (unknown **and** *unknown)* =
  - NOT*:* *(***not** *unknown)* =
  - "*P* **is unknown"** evaluates to true if predicate *P* evaluates to *unknown*
- Result of **where** clause predicate is treated as *false* if it evaluates to *unknown*

Nested Subqueries

- SQL provides a mechanism for the nesting of subqueries.
- A subquery is a **select-from-where** expression that is nested within another query.
- A common use of subqueries is to perform tests for **set membership**, set comparisons, and set cardinality.
- Find all customers who have both an account and a loan at the bank.

```
select distinct customer-name
from borrower
where customer-name in (select customer-name
                        from depositor)
```

- Find all customers who have a loan at the bank but do not have an account at the bank

```
select distinct customer-name
from borrower
where customer-name not in (select customer-name
                            from depositor)
```

Nested Subqueries - Set Comparison

- F <comp> **some** *r* ⇔ ∃ *t* ∈ *r* *s.t.* (F <comp> *t*)
  Where <comp> can be:
  $<, \leq, >, =, \neq$

$(5 < \textbf{some} \begin{array}{|c|}\hline 0\\\hline 5\\\hline 6\\\hline\end{array}) = \text{true}$

(read: 5 < some tuple in the relation)

$(5 < \textbf{some} \begin{array}{|c|}\hline 0\\\hline 5\\\hline\end{array}) = \text{false}$

$(5 = \textbf{some} \begin{array}{|c|}\hline 0\\\hline 5\\\hline\end{array}) = \text{true}$

$(5 \neq \textbf{some} \begin{array}{|c|}\hline 0\\\hline 5\\\hline\end{array}) = \text{true (since } 0 \neq 5)$

(= **some**) ≡ **in**
However, (≠ **some**) $\not\equiv$ **not in**

- F <comp> **all** *r* ⇔ ∀ *t* ∈ *r* (F <comp> *t*)

$(5 < \textbf{all} \begin{array}{|c|}\hline 0\\\hline 5\\\hline 6\\\hline\end{array}) = \text{false}$

$(5 < \textbf{all} \begin{array}{|c|}\hline 6\\\hline 10\\\hline\end{array}) = \text{true}$

$(5 = \textbf{all} \begin{array}{|c|}\hline 4\\\hline 5\\\hline\end{array}) = \text{false}$

$(5 \neq \textbf{all} \begin{array}{|c|}\hline 4\\\hline 6\\\hline\end{array}) = \text{true (since } 5 \neq 4 \text{ and } 5 \neq 6)$

(≠ **all**) ≡ **not in**
However, (= **all**) $\not\equiv$ **in**

Example Query

- Find all branches that have greater assets than some branch located in Brooklyn.

```
select distinct T.branch-name
from branch as T, branch as S
where T.assets > S.assets and
      S.branch-city = 'Brooklyn'
```

OR

```
select branch-name
from branch
where assets > some   (select assets
                        from branch
                        where branch-city = 'Brooklyn')
```

- Find the names of all branches that have greater assets than all branches located in Brooklyn.

Nested Subqueries - Test for Empty Relations

- The **exists** construct returns the value **true** if the argument subquery is nonempty.
  - **exists** $r \Leftrightarrow r \neq \emptyset$
  - **not exists** $r \Leftrightarrow r = \emptyset$
- Find all customers who have an account at all branches located in Brooklyn.

```
select distinct S.customer-name
from depositor as S
where not exists (
        (select branch-name
        from branch
        where branch-city = 'Brooklyn')
        except
        (select R.branch-name
        from depositor as T, account as R
        where T.account-number = R.account-number and
                S.customer-name = T.customer-name))
```


Note that $X - Y = \emptyset \Leftrightarrow X \subseteq Y$

Cannot write this query using = **all** and its variants

Views

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

  create view *v* **as** <query expression>

  where:
  - <query expression> is any legal expression
  - The view name is represented by *v*

- A view consisting of branches and their customers

```
create view all-customer as
    (select branch-name, customer-name
     from depositor, account
     where depositor.account-number = account.account-number)
  union    (select branch-name, customer-name
            from borrower, loan
            where borrower.loan-number = loan.loan-number)
```

- Find all customers of the Perryridge branch

```
select customer-name
from all-customer
where branch-name = 'Perryridge'
```

Derived Relations

- Find the average account balance of those branches where the average account balance is greater than $1200.

  select *branch-name, avg-balance*
  from (select *branch-name,* **avg** *(balance)*
  from *account*
  group by *branch-name)*
  as *result (branch-name, avg-balance)*
  where *avg-balance* > 1200

  Note that we do not need to use the **having** clause, since we compute the temporary (view) relation *result* in the **from** clause, and the attributes of *result* can be used directly in the **where** clause.

Modification of the Database – Deletion

- Delete all account records at the Perryridge branch

```
delete from account
where branch-name = 'Perryridge'
```

- Delete all accounts at every branch located in Needham city.

```
delete from account
  where branch-name in (select branch-name
                        from branch
                        where branch-city = 'Needham')
delete from depositor
  where account-number in
        (select account-number
          from branch, account
          where branch-city = 'Needham'
            and branch.branch-name = account.branch-name)
```

- Delete the record of all accounts with balances below the average at the bank.

```
delete from account
where balance < (select avg (balance)
                 from account)
```


Problem: as we delete tuples from *deposit,* the average balance changes

Solution used in SQL:

1. First, compute **avg** balance and find all tuples to delete
2. Next, delete all tuples found above (without recomputing **avg** or retesting the tuples)

Modification of the Database – Insertion

- Add a new tuple to *account*

  insert into *account*
  values ('A-9732', 'Perryridge',1200)

  or equivalently

  insert into *account (branch-name, balance, account-number)*
  values ('Perryridge', 1200, 'A-9732')

- Add a new tuple to *account* with *balance* set to null

  insert into *account*
  values ('A-777','Perryridge', *null*)

- Provide as a gift for all loan customers of the Perryridge branch, a $200 savings account. Let the loan number serve as the account number for the new savings account

  insert into *account* **select** *loan-number, branch-name,* 200
  from *loan*
  where *branch-name* = 'Perryridge'

  insert into *depositor* **select** *customer-name, loan-number*
  from *loan, borrower*
  where branch-name = 'Perryridge'
  and *loan.account-number* = *borrower.account-number*

The select from where statement is fully evaluated before any of its results are inserted into the relation (otherwise queries like

insert into *table*1 **select** * **from** *table*1

would cause problems

Modification of the Database – Updates

- Increase all accounts with balances over $10,000 by 6%, all other accounts receive 5%.

  update *account*
  set *balance* = *balance* ∗ 1.06
  where *balance* > 10000

  update *account*
  set *balance* = *balance* ∗ 1.05
  where *balance* ≤ 10000

  The order is important

- Update of a View
  - Create a view of all loan data in *loan* relation, hiding the *amount* attribute

    create view *branch-loan* **as**
    select *branch-name, loan-number*
    from *loan*
  - Add a new tuple to *branch-loan*

    insert into *branch-loan*
    values ('Perryridge', 'L-307')

    This insertion must be represented by the insertion of the tuple

    ('L-307', 'Perryridge', *null*)

    into the *loan* relation

Updates on more complex views are difficult or impossible to translate, and hence are disallowed.

Most SQL implementations allow updates only on simple views (without aggregates) defined on a single relation

Joined Relations

- 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>
using (A_1, A_2, ..., A_n)

Joined Relations – Datasets for Examples

- Relation *loan*

loan-number	*branch-name*	*amount*
L-170	Downtown	3000
L-230	Redwood	4000
L-260	Perryridge	1700

- Relation *borrower*

customer-name	*loan-number*
Jones	L-170
Smith	L-230
Hayes	L-155

- Note: borrower information missing for L-260 and loan information missing for L-155

Joined Relations – Examples

- *loan* **inner join** *borrower* **on**
  loan.loan-number = borrower.loan-number

loan-number	*branch-name*	*amount*	*customer-name*	*loan-number*
L-170	Downtown	3000	Jones	L-170
L-230	Redwood	4000	Smith	L-230

- *loan* **left outer join** *borrower* **on**
  loan.loan-number = borrower.loan-number

loan-number	*branch-name*	*amount*	*customer-name*	*loan-number*
L-170	Downtown	3000	Jones	L-170
L-230	Redwood	4000	Smith	L-230
L-260	Perryridge	1700	*null*	*null*

Joined Relations – Examples

- *loan* **natural inner join** *borrower*

loan-number	*branch-name*	*amount*	*customer-name*
L-170	Downtown	3000	Jones
L-230	Redwood	4000	Smith

- loan **natural right outer join** *borrower*

loan-number	*branch-name*	*amount*	*customer-name*
L-170	Downtown	3000	Jones
L-230	Redwood	4000	Smith
L-155	null	null	Hayes

Joined Relations – Examples

- *loan* **full outer join** *borrower* **using** *(loan-number)*

loan-number	*branch-name*	*amount*	*customer-name*
L-170	Downtown	3000	Jones
L-230	Redwood	4000	Smith
L-260	Perryridge	1700	*null*
L-155	null	null	Hayes

- Find all customers who have either an account or a loan (but not both) at the bank.

  select *customer-name*
  from (*depositor* **natural full outer join** *borrower*)
  where *account-number* **is** *null* **or** *loan-number* **is** *null*

Data Definition Language (DDL)

Allows the specification of not only a set of relations but also information about each relation, including:

- The schema for each relation.
- The domain of values associated with each attribute.
- Integrity constraints
- The set of indices to be maintained for each relations.
- Security and authorization information for each relation.
- The physical storage structure of each relation on disk.

Domain Types in SQL

- **char(n).** Fixed length character string, with user-specified length *n.*
- **varchar(n).** Variable length character strings, with user-specified maximum length *n.*
- **int.** Integer (a finite subset of the integers that is machine-dependent).
- **smallint.** Small integer (a machine-dependent subset of the integer domain type).
- **numeric(p,d).** Fixed point number, with user-specified precision of *p* digits, with *n* 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. Declaring an attribute to be **not null** prohibits null values for that attribute.
- **create domain** construct in SQL-92 creates user-defined domain types

  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

Can extract values of individual fields from date/time/timestamp

E.g. **extract** (**year from** r.starttime)

Can cast string types to date/time/timestamp

E.g. **cast** <string-valued-expression> **as date**

Create Table Construct

- An SQL relation 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$_k$))

  – r is the name of the relation
  – each A_i is an attribute name in the schema of relation r
  – D_i is the data type of values in the domain of attribute A_i

- Example:

  create table *branch*
  (*branch-name* char(15) **not null,**
  branch-city char(30),
  assets integer)

Integrity Constraints in Create Table

- **not null**
- **primary key** (A_1, ..., A_n)
- **check** *(P)*, where *P* is a predicate

Example: Declare *branch-name* as the primary key for *branch* and ensure that the values of *assets* are non-negative.

create table *branch*
(*branch-name* char(15),
branch-city char(30)
assets integer,
primary key (*branch-name*),
check (*assets* >= 0))

primary key declaration on an attribute automatically ensures **not null** in SQL-92 onwards, needs to be explicitly stated in SQL-89

Drop and Alter Table Constructs

- The **drop table** command deletes all information about the dropped relation from the database.
- The **alter table** command is used to add attributes to an existing relation.

  alter table *r* **add** *A D*

  where *A* is the name of the attribute to be added to relation *r* and *D* is the domain of *A.*
  - All tuples in the relation are assigned *null* as the value for the new attribute.
- The **alter table** command can also be used to drop attributes of a relation

  alter table *r* **drop** *A*

  where *A* is the name of an attribute of relation *r*
  - Dropping of attributes not supported by many databases