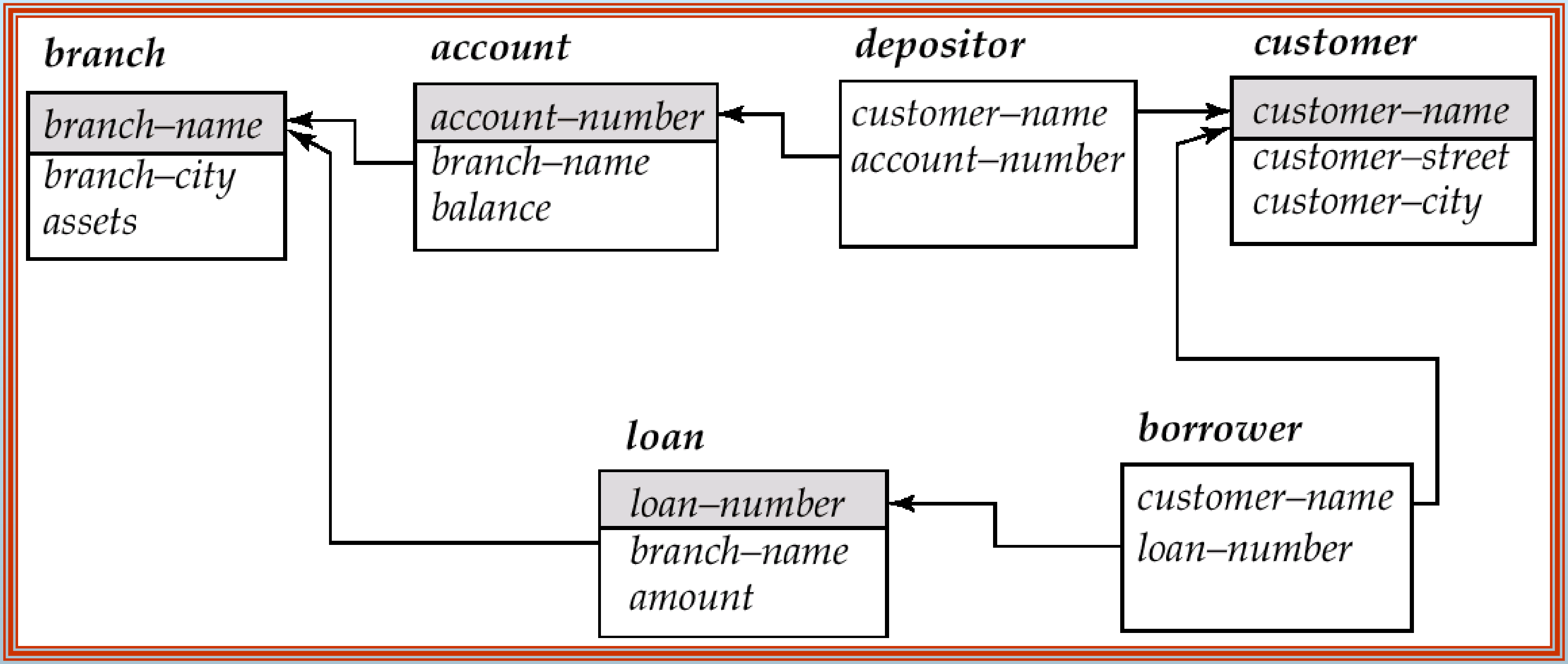
Chapter 4: SQL

- Basic Structure
- Set Operations
- Aggregate Functions
- Null Values
- Nested Subqueries
- Derived Relations
- Views
- Modification of the Database
- Joined Relations
- Data Definition Languages

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 $A_1, A_2, ..., A_n$
  from $r_1, r_2, ..., r_m$
  where P

  - A_is represent attributes
  - r_is represent relations
  - P is a predicate.
- This query is equivalent to the relational algebra expression.

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

- The result of an SQL query is a relation.

The select Clause

- The **select** clause list the attributes desired in the result of a query
  - 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, the query would be:

$$\Pi_{\text{branch-name}}(\textit{loan})$$

- 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!
- NOTE: SQL names are case insensitive, i.e. you can use capital or small letters.
  - You may wish to use upper case where-ever we use bold font.

The select Clause (Cont.)

- SQL allows duplicates in relations as well as in query results.
- To force the elimination of duplicates, insert the keyword **distinct** after **select.**
- Find the names of all branches in the *loan* relations, and remove duplicates

  select distinct *branch-name*
  from *loan*

- The keyword **all** specifies that duplicates not be removed.

  select all *branch-name*
  from *loan*

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 the result must satisfy
  - 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.

The where Clause (Cont.)

- 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.

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

The Rename Operation

- The SQL allows renaming relations and attributes using the **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

- Tuple variables are defined in the **from** clause via the use of the **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. $\boldsymbol{\sigma_\theta (r_1)}$**:** If there are c_1 copies of tuple t_1 in r_1, and t_1 satisfies selections σ_θ, then there are c_1 copies of t_1 in $\sigma_\theta (r_1)$.
2. $\boldsymbol{\Pi_A (r_1)}$**:** 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. $\boldsymbol{r_1 \times r_2}$ **:** 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 $r_1 \times r_2$

Duplicates (Cont.)

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

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

- Then $\Pi_B(r_1)$ would be {(a), (a)}, while $\Pi_B(r_1)$ x r_2 would be

  $\{(a,2), (a,2), (a,3), (a,3), (a,3), (a,3)\}$

- SQL duplicate semantics:

  select $A_{1,}, A_2, ..., A_n$
  from $r_1, r_2, ..., r_m$
  where P

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

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

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*

Set Operations

- 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.

  (**select** *customer-name* **from** *depositor*)
  intersect
  (select *customer-name* **from** *borrower)*

- Find all customers who have an account but no loan.

  (**select** *customer-name* **from** *depositor*)
  except
  (select *customer-name* **from** *borrower)*

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

Aggregate Functions (Cont.)

- 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.

select count (distinct *customer-name)*
from *depositor*

Aggregate Functions – Group By

- 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*

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

Aggregate Functions – Having Clause

- 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

Note: 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 which appear in the *loan* relation 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
- However, aggregate functions simply ignore nulls
  - more on this shortly

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*) = *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*
- Result of **where** clause predicate is treated as *false* if it evaluates to *unknown*

Null Values and Aggregates

- Total all loan amounts

  select sum (*amount)*
  from *loan*

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

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.

Example Query

- 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)
```

Example Query

- Find all customers who have both an account and a loan at the Perryridge branch

select distinct *customer-name*
from *borrower, loan*
where *borrower.loan-number* = *loan.loan-number* **and**
branch-name = “Perryridge” **and**
(branch-name, customer-name) **in**
(select *branch-name, customer-name*
from *depositor, account*
where *depositor.account-number* =
account.account-number)

- Note: Above query can be written in a much simpler manner. The formulation above is simply to illustrate SQL features.

(Schema used in this example)

Set Comparison

- 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'

- Same query using > **some** clause

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

Definition of Some Clause

- F <comp> **some** *r* $\Leftrightarrow \exists\, t \in r$ *s.t.* (F <comp> *t*)
  Where <comp> can be: $<, \leq, >, =, \neq$

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

(read: 5 < some tuple in the relation)

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

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

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

(= **some**) $\equiv$ **in**

However, ($\neq$ **some**) $\not\equiv$ **not in**

Definition of all Clause

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

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

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

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

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

($\neq$ **all**) ≡ **not in**

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

Example Query

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

select *branch-name*
from *branch*
where *assets* > **all**
(select *assets*
from *branch*
where *branch-city* = 'Brooklyn')

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** $r \Leftrightarrow r = \emptyset$

Example Query

- 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))
```

- (Schema used in this example)
- Note that $X - Y = \varnothing \quad \Leftrightarrow \quad X \subseteq Y$
- *Note:* Cannot write this query using = **all** and its variants

Test for Absence of Duplicate Tuples

- The **unique** construct tests whether a subquery has any duplicate tuples in its result.
- Find all customers who have at most one account at the Perryridge branch.

  select *T.customer-name*
  from *depositor* **as** *T*
  where unique (

  select *R.customer-name*
  from *account, depositor* **as** *R*
  where *T.customer-name* = *R.customer-name* **and**
  R.account-number = *account.account-number* **and**
  account.branch-name = 'Perryridge')

- (Schema used in this example)

Example Query

- Find all customers who have at least two accounts at the Perryridge branch.

    select distinct *T.customer-name*
    from *depositor T*
    where not unique (
        select *R.customer-name*
        from *account, depositor* **as** *R*
        where *T.customer-name* = *R.customer-name*
    and
        R.account-number = *account.account-number*
    and
        account.branch-name = 'Perryridge')

- (Schema used in this example)

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*

Example Queries

- 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)*

- (Schema used in this example)

Example Query

- 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*)

Modification of the Database – Insertion

- 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%.
  - Write two **update** statements:

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

    update *account*
    set *balance* = *balance* ∗ 1.05
    where *balance* ≤ 10000
  - The order is important
  - Can be done better using the **case** statement (next slide)

Case Statement for Conditional Updates

- Same query as before: Increase all accounts with balances over \$10,000 by 6%, all other accounts receive 5%.

```
update account
set balance =  case
                   when balance <= 10000 then balance *1.05
                   else   balance * 1.06
               end
```

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 (Cont.)

- **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

The *loan* and *borrower* Relations

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

loan

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

borrower

The Result of *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

The Result of *loan* left outer join *borrower* on *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*

The Result of *loan* natural inner join *borrower*

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

Join Types and Join Conditions

Join types	Join Conditions
inner join	**natural**
left outer join	**on** <predicate>
right outer join	**using** $(A_1, A_1, \ldots, A_n)$
full outer join	

The Result of *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

The Result of *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

SQL Data Definition for Part of the Bank Database

create table *customer*
  (*customer-name* **char**(20),
  customer-street **char**(30),
  customer-city **char**(30),
  primary key (*customer-name*))

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

create table *account*
  (*account-number* **char**(10),
  branch-name **char**(15),
  balance **integer**,
  primary key (*account-number*),
  check (*balance* >= 0))

create table *depositor*
  (*customer-name* **char**(20),
  account-number **char**(10),
  primary key (*customer-name*, *account-number*))