Chapter 4: SQL

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

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 $P$
  ```

  - $A_i$s represent attributes
  - $r_i$s represent relations
  - $P$ is a predicate.

  - This query is equivalent to the relational algebra expression:
    
    $$\Pi_{A_1, A_2, ..., A_n}(\sigma_P(r_1 \times r_2 \times \ldots \times r_m))$$

  - The result of an SQL query is a relation.
The select Clause

- The select clause corresponds to the projection operation of the relational algebra. It is used to list the attributes desired in the result of a query.

- Find the names of all branches in the loan relation
  
  \[
  \text{select} \text{branch-name} \\
  \text{from} \text{loan}
  \]

  In the “pure” relational algebra syntax, this query would be:

  \[\Pi_{\text{branch-name}}(\text{loan})\]

- An asterisk in the select clause denotes “all attributes”

  \[
  \text{select} \ast \\
  \text{from} \text{loan}
  \]

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 relation, and remove duplicates

  \[
  \text{select distinct} \text{branch-name} \\
  \text{from} \text{loan}
  \]

- The keyword all specifies that duplicates not be removed.

  \[
  \text{select all} \text{branch-name} \\
  \text{from} \text{loan}
  \]
The select Clause (Cont.)

- The `select` clause can contain arithmetic expressions involving the operators, `+`, `−`, `∗`, and `/`, and operating on constants or attributes of tuples.
- The query:
  
  ```
  select branch-name, loan-number, amount * 100
  from loan
  ```

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

The where Clause

- The `where` clause corresponds to the selection predicate of the relational algebra. It consists of a predicate involving attributes of the relations that appear in the `from` clause.
- Find all loan numbers 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
  ```

- SQL uses the logical connectives `and`, `or`, and `not`. It allows the use of arithmetic expressions as operands to the comparison operators.
The where Clause (Cont.)

- SQL includes a **between** comparison operator in order to simplify **where** clauses that specify that a value be less than or equal to some value and greater than or equal to some other value.

- Find the loan number of those loans with loan amounts between $90,000 and $100,000 (that is, \( \geq 90,000 \) and \( \leq 100,000 \))

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

The from Clause

- The **from** clause corresponds to the Cartesian product operation of the relational algebra. It lists the relations to be scanned in the evaluation of the expression.

- Find the Cartesian product **borrower \times loan**

```
select *
from borrower, loan
```

- Find the name and loan number of all customers having a loan at the Perryridge branch.

```
select distinct customer-name, borrower.loan-number
from borrower, loan
where borrower.loan-number = loan.loan-number and branch-name = "Perryridge"
```
The Rename Operation

- The SQL mechanism for renaming relations and attributes is accomplished through the as clause:

  \[
  \text{old-name as new-name}
  \]

- Find the name and loan number of all customers having a loan at the Perryridge branch; replace the column name loan-number with the name loan-id.

  \[
  \text{select distinct customer-name, borrower.loan-number as loan-id from borrower, loan}
  \\
  \text{where borrower.loan-number = loan.loan-number and}
  \\
  \text{branch-name = “Perryridge”}
  \]

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.

  \[
  \text{select distinct customer-name, T.loan-number}
  \\
  \text{from borrower as T, loan as S}
  \\
  \text{where T.loan-number = S.loan-number}
  \]

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

  \[
  \text{select distinct T.branch-name}
  \\
  \text{from branch as T, branch as S}
  \\
  \text{where T.assets > S.assets and S.branch-city = “Brooklyn”}
  \]
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’.
  
  ```sql
  select customer-name
  from customer
  where customer-street like "%Main%"
  ```
- Match the name “Main%”
  
  ```sql
  like "Main\%" escape "\"
  ```

Ordering the Display of Tuples

- List in alphabetic order the names of all customers having a loan at Perryridge branch
  
  ```sql
  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.
- SQL must perform a sort to fulfill an order by request. Since sorting a large number of tuples may be costly, it is desirable to sort only when necessary.
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. If there are \( c_1 \) copies of tuple \( t_1 \) in \( r_1 \), and \( t_1 \) satisfies selection \( \sigma_{\theta}(t_1) \), then there are \( c_1 \) copies of \( t_1 \) in \( \sigma_{\theta}(r_1) \).
2. 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. 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 \( r_1 \times r_2 \).

Suppose relations \( r_1 \) with schema \((A, B)\) and \( r_2 \) with schema \((C)\) are the following multisets:

\[
\begin{align*}
    r_1 &= \{(1, a), (2, a)\} & r_2 &= \{(2), (3), (3)\}
\end{align*}
\]

Then \( \Pi_B(r_1) \) would be \( \{(a), (a)\} \), while \( \Pi_B(r_1) \times r_2 \) would be

\[
\{(a, 2), (a, 2), (a, 3), (a, 3), (a, 3), (a, 3)\}
\]

**SQL duplicate semantics:**

\[
\begin{align*}
    \text{select} & \quad A_1, A_2, \ldots, A_n \\
    \text{from} & \quad r_1, r_2, \ldots, r_m \\
    \text{where} & \quad P
\end{align*}
\]

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

\[
\Pi_{A_1, A_2, \ldots, A_n}(\sigma_{\theta}(r_1 \times r_2 \times \ldots \times r_m))
\]
Set Operations

- The set operations **union**, **intersect**, and **except** operate on relations and correspond to the relational algebra operations $\cup$, $\cap$, and $-$. 

- 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:
  
  $$(\text{select customer-name from depositor}) \cup (\text{select customer-name from borrower})$$

- Find all customers who have both a loan and an account.
  
  $$(\text{select customer-name from depositor}) \cap (\text{select customer-name from borrower})$$

- Find all customers who have an account but no loan.
  
  $$(\text{select customer-name from depositor}) \setminus (\text{select customer-name from borrower})$$
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.

  ```sql
  select avg (balance)
  from account
  where branch-name = "Perryridge"
  ```

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

  ```sql
  select count (*)
  from customer
  ```

- Find the number of depositors in the bank

  ```sql
  select count (distinct customer-name)
  from depositor
  ```
Aggregate Functions – Group By

- Find the number of depositors for each branch.

```sql
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

```sql
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.
Null Values

- It is possible for tuples to have a null value, denoted by \textit{null}, for some of their attributes; \textit{null} signifies an unknown value or that a value does not exist.
- The result of any arithmetic expression involving \textit{null} is \textit{null}.
- Roughly speaking, all comparisons involving \textit{null} return \textit{false}. More precisely,
  - Any comparison with \textit{null} returns \textit{unknown}
  - \((\text{true or unknown}) = \text{true}, \quad (\text{false or unknown}) = \text{unknown}
    \quad (\text{unknown or unknown}) = \text{unknown},
    \quad (\text{true and unknown}) = \text{unknown}, \quad (\text{false and unknown}) = \text{false},
    \quad (\text{unknown and unknown}) = \text{unknown})
  - Result of \textit{where} clause predicate is treated as \textit{false} if it evaluates to \textit{unknown}
  - “\textit{P is unknown}” evaluates to true if predicate \textit{P} evaluates to \textit{unknown}

Null Values (Cont.)

- Find all loan numbers which appear in the \textit{loan} relation with null values for \textit{amount}.
  
  \begin{verbatim}
  select loan-number
  from loan
  where amount is null
  \end{verbatim}

- Total all loan amounts
  
  \begin{verbatim}
  select sum \textit{(amount)}
  from loan
  \end{verbatim}

  Above statement ignores null amounts; result is null if there is no non-null amount.

- All aggregate operations except \texttt{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.

**Set Membership**

- \( F \in r \iff \exists t \in r (t = F) \)

<table>
<thead>
<tr>
<th>0</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>(5 in 4) = true</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>0</th>
<th>4</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>(5 in 4) = false</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>0</th>
<th>4</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>(5 not in 4) = true</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Example Query

- Find all customers who have both an account and a loan at bank.

```sql
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.

```sql
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.

```sql
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)
```
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"
```

The Some Clause

- \( F \text{ <comp> some } r \iff \exists t(t \in r \land [F \text{ <comp> } t]) \)
  Where \( <\text{comp}> \) can be: \( <, \leq, >, \geq, =, \neq \)

\[
\begin{align*}
(5 < \text{some} & 5) = \text{true} \\
(5 < \text{some} & 6) = \text{false} \\
(5 = \text{some} & 0) = \text{true} \\
(5 \neq \text{some} & 0) = \text{true} \\
\end{align*}
\]

(read: 5 < some tuple in the relation)

- \( (= \text{some}) \equiv \text{in} \)
- However, \( (\neq \text{some}) \neq \text{not in} \)
Example Query

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

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

The All Clause

- \( F < \text{comp} > \text{all} \ r \leftrightarrow \forall t (t \in r \land [F < \text{comp} > t]) \)

<table>
<thead>
<tr>
<th></th>
<th>5</th>
<th>6</th>
</tr>
</thead>
</table>
| (5 < all | 5 | 6 | = false
| 6      |
| (5 < all | 6 | 10| = true
| 4      |
| (5 = all | 5 | 4 | = false
| 4      |
| (5 ≠ all | 6 | 6 | = true (since 5 ≠ 4 and 5 ≠ 6)

- \( \neq \text{all} \equiv \text{not in} \)
- However, \( = \text{all} \not\in \)
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")
```
Example Query

- Find all customers who have an account at all branches located in Brooklyn.

```sql
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 \( X - Y = \emptyset \iff X \subseteq Y \)

---

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 only one account at the Perryridge branch.

```sql
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")
```
Example Query

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

```sql
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")
```

Derived Relations

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

```sql
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 in the **from** clause the temporary relation **result**, and the attributes of **result** can be used directly in the **where** clause.
Views

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

  ```sql
  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

  ```sql
  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

  ```sql
  select customer-name
  from all-customer
  where branch-name = "Perryridge"
  ```
Modification of the Database – Deletion

- Delete all account records at the Perryridge branch
  
  ```sql
  delete from account
  where branch-name = "Perryridge"
  ```

- Delete all accounts at every branch located in Needham.
  
  ```sql
  delete from account
  where branch-name in (select branch-name
                          from branch
                          where branch-city = "Needham")
  ```

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

Example Query

- Delete the records of all accounts with balances below the average at the bank
  
  ```sql
  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*
  
  ```sql
  insert into account
  values ("Perryridge", A-9732, 1200)
  ```

  or equivalently

  ```sql
  insert into account (branch-name, balance, account-number)
  values ("Perryridge", 1200, A-9732)
  ```

- Add a new tuple to *account* with *balance* set to null
  
  ```sql
  insert into account
  values ("Perryridge", A-777, 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
  
  ```sql
  insert into account
  select branch-name, loan-number, 200
  from loan
  where branch-name = "Perryridge"
  ```

  ```sql
  insert into depositor
  select customer-name, loan-number
  from loan, borrower
  where branch-name = "Perryridge"
  and loan.account-number = borrower.account-number
  ```
Modification of the Database – Updates

- Increase all accounts with balances over $10,000 by 6%, all other accounts receive 5%.
  - Write two update statements:
    
    ```sql
    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 (Exercise 4.11)

Update of a View

- Create a view of all loan data in the loan relation, hiding the amount attribute
  
  ```sql
  create view branch-loan as
  select branch-name, loan-number
  from loan
  ```

- Add a new tuple to branch-loan
  
  ```sql
  insert into branch-loan
  values ("Perryridge", "L-307")
  ```
  
  This insertion must be represented by the insertion of the tuple
  
  ("Perryridge", “L-307”, null)

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

<table>
<thead>
<tr>
<th>Join Types</th>
<th>Join Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>inner join</td>
<td>natural</td>
</tr>
<tr>
<td>left outer join</td>
<td>on &lt;predicate&gt;</td>
</tr>
<tr>
<td>right outer join</td>
<td>using ((A_1, A_2, \ldots, A_n))</td>
</tr>
<tr>
<td>full outer join</td>
<td></td>
</tr>
</tbody>
</table>

**Joined Relations – Datasets for Examples**

- Relation *loan*

<table>
<thead>
<tr>
<th>branch-name</th>
<th>loan-number</th>
<th>amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Downtown</td>
<td>L-170</td>
<td>3000</td>
</tr>
<tr>
<td>Redwood</td>
<td>L-230</td>
<td>4000</td>
</tr>
<tr>
<td>Perryridge</td>
<td>L-260</td>
<td>1700</td>
</tr>
</tbody>
</table>

- Relation *borrower*

<table>
<thead>
<tr>
<th>customer-name</th>
<th>loan-number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jones</td>
<td>L-170</td>
</tr>
<tr>
<td>Smith</td>
<td>L-230</td>
</tr>
<tr>
<td>Hayes</td>
<td>L-155</td>
</tr>
</tbody>
</table>
### Joined Relations – Examples

- **loan inner join** borrower on
  \[ \text{loan.loan-number} = \text{borrower.loan-number} \]

<table>
<thead>
<tr>
<th>branch-name</th>
<th>loan-number</th>
<th>amount</th>
<th>customer-name</th>
<th>loan-number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Downtown</td>
<td>L-170</td>
<td>3000</td>
<td>Jones</td>
<td>L-170</td>
</tr>
<tr>
<td>Redwood</td>
<td>L-230</td>
<td>4000</td>
<td>Smith</td>
<td>L-230</td>
</tr>
</tbody>
</table>

- **loan left outer join** borrower on
  \[ \text{loan.loan-number} = \text{borrower.loan-number} \]

<table>
<thead>
<tr>
<th>branch-name</th>
<th>loan-number</th>
<th>amount</th>
<th>customer-name</th>
<th>loan-number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Downtown</td>
<td>L-170</td>
<td>3000</td>
<td>Jones</td>
<td>L-170</td>
</tr>
<tr>
<td>Redwood</td>
<td>L-230</td>
<td>4000</td>
<td>Smith</td>
<td>L-230</td>
</tr>
<tr>
<td>Perryridge</td>
<td>L-260</td>
<td>1700</td>
<td>null</td>
<td>null</td>
</tr>
</tbody>
</table>

- **loan natural inner join** borrower

<table>
<thead>
<tr>
<th>branch-name</th>
<th>loan-number</th>
<th>amount</th>
<th>customer-name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Downtown</td>
<td>L-170</td>
<td>3000</td>
<td>Jones</td>
</tr>
<tr>
<td>Redwood</td>
<td>L-230</td>
<td>4000</td>
<td>Smith</td>
</tr>
</tbody>
</table>

- **loan natural right outer join** borrower

<table>
<thead>
<tr>
<th>branch-name</th>
<th>loan-number</th>
<th>amount</th>
<th>customer-name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Downtown</td>
<td>L-170</td>
<td>3000</td>
<td>Jones</td>
</tr>
<tr>
<td>Redwood</td>
<td>L-230</td>
<td>4000</td>
<td>Smith</td>
</tr>
<tr>
<td>null</td>
<td>L-155</td>
<td>null</td>
<td>Hayes</td>
</tr>
</tbody>
</table>
Joined Relations – Examples

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

<table>
<thead>
<tr>
<th>branch-name</th>
<th>loan-number</th>
<th>amount</th>
<th>customer-name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Downtown</td>
<td>L-170</td>
<td>3000</td>
<td>Jones</td>
</tr>
<tr>
<td>Redwood</td>
<td>L-230</td>
<td>4000</td>
<td>Smith</td>
</tr>
<tr>
<td>Perryridge</td>
<td>L-260</td>
<td>1700</td>
<td>null</td>
</tr>
<tr>
<td>null</td>
<td>L-155</td>
<td>null</td>
<td>Hayes</td>
</tr>
</tbody>
</table>

- 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 relation.
- 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.

Domain Types in SQL (Cont.)

- **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.
- **date**. Dates, containing a (4 digit) year, month and date.
- **time**. Time of day, in hours, minutes and seconds.
  - 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
    ```sql
    create domain person-name char(20) not null
    ```
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, 
  \langle\text{integrity-constraint}_1\rangle, 
  \ldots, 
  \langle\text{integrity-constraint}_k\rangle)`

  - `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) not null, 
  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
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. All tuples in the relation are assigned null as the value for the new attribute. The form of the **alter table** command is

  \[
  \text{alter table } r \text{ add } A \text{ D}
  \]

  where \( A \) is the name of the attribute to be added to relation \( r \) and \( D \) is the domain of \( A \).

- The **alter table** command can also be used to drop attributes of a relation

  \[
  \text{alter table } r \text{ drop } A
  \]

  where \( A \) is the name of an attribute of relation \( r \).

Embedded SQL

- The SQL standard defines embeddings of SQL in a variety of programming languages such as such as Pascal, PL/I, Fortran, C, and Cobol.

- A language in which SQL queries are embedded is referred to as a *host* language, and the SQL structures permitted in the host language comprise **embedded SQL**.

- The basic form of these languages follows that of the System R embedding of SQL into PL/I.

- EXEC SQL statement is used to identify embedded SQL requests to the preprocessor

  \[
  \text{EXEC SQL <embedded SQL statement > END EXEC}
  \]
Example Query

From within a host language, find the names and account numbers of customers with more than the variable \( amount \) dollars in some account.

- Specify the query in SQL and declare a \textit{cursor} for it

EXEC SQL
\begin{verbatim}
decare c cursor for
select customer-name, account-number
from depositor, account
where depositor.account-number = account.account-number
and account.balance > :amount
\end{verbatim}
END-EXEC

Embedded SQL (Cont.)

- The \texttt{open} statement causes the query to be evaluated

EXEC SQL \texttt{open c END-EXEC}

- The \texttt{fetch} statement causes the values of one tuple in the query result to be placed in host language variables.

EXEC SQL \texttt{fetch c into :cn :an END-EXEC}

Repeated calls to \texttt{fetch} get successive tuples in the query result; a variable in the SQL communication area indicates when end-of-file is reached.

- The \texttt{close} statement causes the database system to delete the temporary relation that holds the result of the query.

EXEC SQL \texttt{close c END-EXEC}
**Dynamic SQL**

- Allows programs to construct and submit SQL queries at runtime.
- Example of the use of dynamic SQL from within a C program.

```c
char * sqlprog = "update account set balance = balance * 1.05 where account-number = ?"
EXEC SQL prepare dynprog from :sqlprog;
EXEC SQL execute dynprog using :account;
```

- The dynamic SQL program contains a ?, which is a place holder for a value that is provided when the SQL program is executed.

**Other SQL Features**

- *Fourth-generation languages* – special language to assist application programmers in creating templates on the screen for a user interface, and in formatting data for report generation; available in most commercial database products
- SQL sessions – provide the abstraction of a client and a server (possibly remote)
  - client *connects* to an SQL server, establishing a session
  - executes a series of statements
  - *disconnects* the session
  - can *commit* or *rollback* the work carried out in the session
- An SQL environment contains several components, including a user identifier, and a *schema*, which identifies which of several schemas a session is using.