



Chapter 4 : Intermediate SQL

Database System Concepts, 7th Ed.

©Silberschatz, Korth and Sudarshan

See www.db-book.com for conditions on re-use



Outline

- Join Expressions
- Views
- Transactions
- Integrity Constraints
- SQL Data Types and Schemas
- Index Definition in SQL
- Authorization



Joined Relations

- **Join operations** take two relations and return as a result another relation.
- A join operation is a **Cartesian product** which requires that tuples in the two relations match (under some condition). It also specifies the attributes that are present in the result of the join
- The **join operations** are typically used as **subquery expressions** in the **from clause**
- Three types of joins:
 - **Natural join**
 - **Inner join**
 - **Outer join**



Natural Join in SQL

- Natural join matches tuples with the same values for all common attributes, and retains only one copy of each common column.
- List the names of instructors along with the course ID of the courses that they taught
 - ```
select name, course_id
from students, takes
where student.ID = takes.ID;
```
- Same query in SQL with “natural join” construct
  - ```
select name, course_id
from student natural join takes;
```



Natural Join in SQL (Cont.)

- The **from** clause can have multiple relations combined using natural join:

```
select A1, A2, ... An  
from r1 natural join r2 natural join .. natural join rn  
where P;
```



Student Relation

<i>ID</i>	<i>name</i>	<i>dept_name</i>	<i>tot_cred</i>
00128	Zhang	Comp. Sci.	102
12345	Shankar	Comp. Sci.	32
19991	Brandt	History	80
23121	Chavez	Finance	110
44553	Peltier	Physics	56
45678	Levy	Physics	46
54321	Williams	Comp. Sci.	54
55739	Sanchez	Music	38
70557	Snow	Physics	0
76543	Brown	Comp. Sci.	58
76653	Aoi	Elec. Eng.	60
98765	Bourikas	Elec. Eng.	98
98988	Tanaka	Biology	120



Takes Relation

<i>ID</i>	<i>course_id</i>	<i>sec_id</i>	<i>semester</i>	<i>year</i>	<i>grade</i>
00128	CS-101	1	Fall	2017	A
00128	CS-347	1	Fall	2017	A-
12345	CS-101	1	Fall	2017	C
12345	CS-190	2	Spring	2017	A
12345	CS-315	1	Spring	2018	A
12345	CS-347	1	Fall	2017	A
19991	HIS-351	1	Spring	2018	B
23121	FIN-201	1	Spring	2018	C+
44553	PHY-101	1	Fall	2017	B-
45678	CS-101	1	Fall	2017	F
45678	CS-101	1	Spring	2018	B+
45678	CS-319	1	Spring	2018	B
54321	CS-101	1	Fall	2017	A-
54321	CS-190	2	Spring	2017	B+
55739	MU-199	1	Spring	2018	A-
76543	CS-101	1	Fall	2017	A
76543	CS-319	2	Spring	2018	A
76653	EE-181	1	Spring	2017	C
98765	CS-101	1	Fall	2017	C-
98765	CS-315	1	Spring	2018	B
98988	BIO-101	1	Summer	2017	A
98988	BIO-301	1	Summer	2018	<i>null</i>



student natural join takes

ID	name	dept_name	tot_cred	course_id	sec_id	semester	year	grade
00128	Zhang	Comp. Sci.	102	CS-101	1	Fall	2017	A
00128	Zhang	Comp. Sci.	102	CS-347	1	Fall	2017	A-
12345	Shankar	Comp. Sci.	32	CS-101	1	Fall	2017	C
12345	Shankar	Comp. Sci.	32	CS-190	2	Spring	2017	A
12345	Shankar	Comp. Sci.	32	CS-315	1	Spring	2018	A
12345	Shankar	Comp. Sci.	32	CS-347	1	Fall	2017	A
19991	Brandt	History	80	HIS-351	1	Spring	2018	B
23121	Chavez	Finance	110	FIN-201	1	Spring	2018	C+
44553	Peltier	Physics	56	PHY-101	1	Fall	2017	B-
45678	Levy	Physics	46	CS-101	1	Fall	2017	F
45678	Levy	Physics	46	CS-101	1	Spring	2018	B+
45678	Levy	Physics	46	CS-319	1	Spring	2018	B
54321	Williams	Comp. Sci.	54	CS-101	1	Fall	2017	A-
54321	Williams	Comp. Sci.	54	CS-190	2	Spring	2017	B+
55739	Sanchez	Music	38	MU-199	1	Spring	2018	A-
76543	Brown	Comp. Sci.	58	CS-101	1	Fall	2017	A
76543	Brown	Comp. Sci.	58	CS-319	2	Spring	2018	A
76653	Aoi	Elec. Eng.	60	EE-181	1	Spring	2017	C
98765	Bourikas	Elec. Eng.	98	CS-101	1	Fall	2017	C-
98765	Bourikas	Elec. Eng.	98	CS-315	1	Spring	2018	B
98988	Tanaka	Biology	120	BIO-101	1	Summer	2017	A
98988	Tanaka	Biology	120	BIO-301	1	Summer	2018	null



Dangerous in Natural Join

- Beware of **unrelated attributes** with same name which get equated incorrectly
- Example -- List the names of students instructors along with the titles of courses that they have taken
 - **Correct version**

```
select name, title  
from student natural join takes, course  
where takes.course_id = course.course_id;
```

- **Incorrect version**

```
select name, title  
from student natural join takes natural join course;
```

- This query omits all (student name, course title) pairs where the student takes a course in a department other than the student's own department.
- The correct version (above), correctly outputs such pairs.



Outer Join

- An extension of the join operation that avoids loss of information.
- Computes the join and then adds tuples from one relation that does not match tuples in the other relation to the result of the join.
- Uses *null* values.
- Three forms of outer join:
 - left outer join
 - right outer join
 - full outer join



Outer Join Examples

- Relation *course*

<i>course_id</i>	<i>title</i>	<i>dept_name</i>	<i>credits</i>
BIO-301	Genetics	Biology	4
CS-190	Game Design	Comp. Sci.	4
CS-315	Robotics	Comp. Sci.	3

- Relation *prereq*

<i>course_id</i>	<i>prereq_id</i>
BIO-301	BIO-101
CS-190	CS-101
CS-347	CS-101

- Observe that

course information is missing CS-437

prereq information is missing CS-315

- \times



Left Outer Join

- *course natural left outer join prereq*

<i>course_id</i>	<i>title</i>	<i>dept_name</i>	<i>credits</i>	<i>prereq_id</i>
BIO-301	Genetics	Biology	4	BIO-101
CS-190	Game Design	Comp. Sci.	4	CS-101
CS-315	Robotics	Comp. Sci.	3	<i>null</i>

- In relational algebra: *course ⋗ prereq*



Right Outer Join

- *course natural right outer join prereq*

<i>course_id</i>	<i>title</i>	<i>dept_name</i>	<i>credits</i>	<i>prereq_id</i>
BIO-301	Genetics	Biology	4	BIO-101
CS-190	Game Design	Comp. Sci.	4	CS-101
CS-347	<i>null</i>	<i>null</i>	<i>null</i>	CS-101

- In relational algebra: *course ⋗ prereq*



Full Outer Join

- *course natural full outer join prereq*

course_id	title	dept_name	credits	prereq_id
BIO-301	Genetics	Biology	4	BIO-101
CS-190	Game Design	Comp. Sci.	4	CS-101
CS-315	Robotics	Comp. Sci.	3	null
CS-347	null	null	null	CS-101

- In relational algebra: *course ⋗ prereq*



Joined Types and Conditions

- **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.
- **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.

<i>Join types</i>
inner join
left outer join
right outer join
full outer join

<i>Join conditions</i>
natural
on < predicate >
using (A₁, A₂, ..., A_n)



Joined Relations – Examples

- *course* **natural right outer join** *prereq*

course_id	title	dept_name	credits	prereq_id
BIO-301	Genetics	Biology	4	BIO-101
CS-190	Game Design	Comp. Sci.	4	CS-101
CS-347	null	null	null	CS-101

- *course* **full outer join** *prereq* **using** (*course_id*)

course_id	title	dept_name	credits	prereq_id
BIO-301	Genetics	Biology	4	BIO-101
CS-190	Game Design	Comp. Sci.	4	CS-101
CS-315	Robotics	Comp. Sci.	3	null
CS-347	null	null	null	CS-101



Joined Relations – Examples

- ***course inner join prereq on***
course.course_id = prereq.course_id



course_id	title	dept_name	credits	prereq_id	course_id
BIO-301	Genetics	Biology	4	BIO-101	BIO-301
CS-190	Game Design	Comp. Sci.	4	CS-101	CS-190

- What is the difference between the above, and a natural join?
- ***course left outer join prereq on***
course.course_id = prereq.course_id

course_id	title	dept_name	credits	prereq_id	course_id
BIO-301	Genetics	Biology	4	BIO-101	BIO-301
CS-190	Game Design	Comp. Sci.	4	CS-101	CS-190
CS-315	Robotics	Comp. Sci.	3	null	null



Joined Relations – Examples

- *course natural right outer join prereq*

course_id	title	dept_name	credits	prereq_id
BIO-301	Genetics	Biology	4	BIO-101
CS-190	Game Design	Comp. Sci.	4	CS-101
CS-347	null	null	null	CS-101

- *course full outer join prereq using (course_id)*

course_id	title	dept_name	credits	prereq_id
BIO-301	Genetics	Biology	4	BIO-101
CS-190	Game Design	Comp. Sci.	4	CS-101
CS-315	Robotics	Comp. Sci.	3	null
CS-347	null	null	null	CS-101



Views

- In some cases, it is not desirable for all users to see the entire logical model (that is, all the actual relations stored in the database.)
- Consider a person who needs to know an instructors name and department, but not the salary. This person should see a relation described, in SQL, by

```
select ID, name, dept_name
      from instructor
```

- A **view** provides a mechanism to **hide certain data** from the view of certain users.
- Any relation that is not of the conceptual model but is made visible to a user as a “virtual relation” is called a **view**.



View Definition

- A view is defined using the **create view** statement which has the form

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

where <query expression> is any legal SQL expression. The view name is represented by *v*.

- Once a view is defined, the view name can be used to refer to the **virtual relation** that the view generates.
- View definition is not the same as creating a new relation by evaluating the query expression
 - Rather, a **view definition** causes the **saving of an expression**; the expression is substituted into queries using the view.



View Definition and Use

- A view of instructors without their salary

```
create view faculty as  
    select ID, name, dept_name  
        from instructor
```

- Find all instructors in the Biology department

```
select name  
from faculty  
where dept_name = 'Biology'
```

- Create a view of department salary totals

 **create view departments_total_salary(dept_name, total_salary) as**

```
select dept_name, sum (salary)  
    from instructor  
group by dept_name,
```



Views Defined Using Other Views

- One view may be used in the expression defining another view
- A view relation v_1 is said to ***depend directly*** on a view relation v_2 if v_2 is used in the expression defining v_1
- A view relation v_1 is said to ***depend on*** view relation v_2 if either v_1 depends directly to v_2 or there is a path of dependencies from v_1 to v_2
- A view relation v is said to be ***recursive*** if it depends on itself.



Views Defined Using Other Views

- **create view *physics_fall_2017* as**
select course.course_id, sec_id, building, room_number
from course, section
where course.course_id = section.course_id
and course.dept_name = 'Physics'
and section.semester = 'Fall'
and section.year = '2017';
- **create view *physics_fall_2017_watson* as**
select course_id, room_number
from *physics_fall_2017*
where building = 'Watson';



View Expansion

- Expand the view :

```
create view physics_fall_2017_watson as  
  select course_id, room_number  
  from physics_fall_2017  
  where building= 'Watson'
```

- To:

```
create view physics_fall_2017_watson as  
  select course_id, room_number  
  from (select course.course_id, building, room_number  
        from course, section  
       where course.course_id = section.course_id  
         and course.dept_name = 'Physics'  
         and section.semester = 'Fall'  
         and section.year = '2017')  
  where building= 'Watson';
```



View Expansion (Cont.)

- A way to define the meaning of views defined in terms of other views.
- Let view v_1 be defined by an expression e_1 that may itself contain uses of view relations.
- View expansion of an expression repeats the following replacement step:

repeat
 Find any view relation v_i in e_1
 Replace the view relation v_i by the expression defining v_i
until no more view relations are present in e_1
- As long as the view definitions are not recursive, this loop will terminate



Materialized Views

- Certain database systems allow view relations to be physically stored.
 - Physical copy created when the view is defined.
 - Such views are called **Materialized view**:
- If relations used in the query are updated, the materialized view result becomes out of date
 - Need to **Maintain** the view, by updating the view whenever the underlying relations are updated.



Update of a View

- Add a new tuple to *faculty* view which we defined earlier

```
insert into faculty
```

```
values ('30765', 'Green', 'Music');
```

- This insertion must be represented by the insertion into the *instructor* relation
 - Must have a value for salary.
- Two approaches
 - Reject the insert
 - Insert the tuple
('30765', 'Green', 'Music', null)
into the *instructor* relation



Some Updates Cannot be Translated Uniquely

- **create view *instructor_info* as**
select *ID*, *name*, *building*
from *instructor*, *department*
where *instructor.dept_name*= *department.dept_name*;
- **insert into *instructor_info***
values ('69987', 'White', 'Taylor');
- Issues
 - Which department, if multiple departments in Taylor?
 - What if no department is in Taylor?



And Some Not at All

- **create view** *history_instructors* **as**
select *
from *instructor*
where *dept_name*= 'History';
- What happens if we insert
('25566', 'Brown', 'Biology', 100000)
into *history_instructors*?



View Updates in SQL

- Most SQL implementations allow updates only on simple views
 - The **from** clause has only one database relation.
 - The **select** clause contains only attribute names of the relation, and does not have any expressions, aggregates, or **distinct** specification.
 - Any attribute not listed in the **select** clause can be set to null
 - The query does not have a **group by** or **having** clause.



Transactions

- A **transaction** consists of a sequence of query and/or update statements and is a “unit” of work
- The SQL standard specifies that a transaction begins implicitly when an SQL statement is executed.
- The transaction must end with one of the following statements:
 - **Commit work.** The updates performed by the transaction become permanent in the database.
 - **Rollback work.** All the updates performed by the SQL statements in the transaction are undone.
- **Atomic transaction**
 - either fully executed or rolled back as if it never occurred
- **Isolation from concurrent transactions**



Integrity Constraints

- Integrity constraints guard against **accidental damage** to the database, by ensuring that authorized changes to the database do not result in a loss of data consistency.
 - A checking account must have a balance **greater than** \$10,000.00
 - A salary of a bank employee must be **at least** \$4.00 an hour
 - A customer must have a **(non-null)** phone number



Constraints on a Single Relation

- **not null**
- **primary key**
- **unique**
- **check (P)**, where P is a predicate



Not Null Constraints

- **not null**

- Declare *name* and *budget* to be **not null**

name varchar(20) **not null**

budget numeric(12,2) **not null**



Unique Constraints

- **unique (A_1, A_2, \dots, A_m)**
 - The unique specification states that the attributes A_1, A_2, \dots, A_m form a candidate key.
 - Candidate keys are permitted to be null (in contrast to primary keys).



The check clause

- The **check (P)** clause specifies a predicate P that must be satisfied by every tuple in a relation.
- Example: ensure that **semester** is one of fall, winter, spring or summer

```
create table section
  (course_id varchar (8),
   sec_id varchar (8),
   semester varchar (6),
   year numeric (4,0),
   building varchar (15),
   room_number varchar (7),
   time slot id varchar (4),
   primary key (course_id, sec_id, semester, year),
   check (semester in ('Fall', 'Winter', 'Spring', 'Summer')))
```



Referential Integrity

- Ensures that a value that appears in one relation for a given set of attributes also appears for a certain set of attributes in another relation.
 - Example: If “Biology” is a department name appearing in one of the tuples in the *instructor* relation, then there exists a tuple in the *department* relation for “Biology”.
- Let A be a set of attributes. Let R and S be two relations that contain attributes A and where A is the primary key of S. A is said to be a **foreign key** of R if for any values of A appearing in R these values also appear in S.



Referential Integrity (Cont.)

- Foreign keys can be specified as part of the SQL **create table** statement
foreign key (*dept_name*) references *department*
- By default, a foreign key references the **primary-key attributes** of the referenced table.
- SQL allows a list of attributes of the referenced relation to be specified explicitly.
foreign key (*dept_name*) references *department* (*dept_name*)



Cascading Actions in Referential Integrity

- When a referential-integrity constraint is violated, the normal procedure is to reject the action that caused the violation.
- An alternative, in case of delete or update is to cascade

```
create table course (
    ...
    dept_name varchar(20),
    foreign key (dept_name) references department
        on delete cascade
        on update cascade,
    . . .)
```

- Instead of cascade we can use :
 - set null,
 - set default



Integrity Constraint Violation During Transactions

- Consider:

```
create table person (
    ID char(10),
    name char(40),
    mother char(10),
    father char(10),
    primary key ID,
    foreign key father references person,
    foreign key mother references person)
```

- How to insert a tuple without causing constraint violation?
 - Insert father and mother of a person before inserting person
 - OR, set father and mother to null initially, update after inserting all persons (not possible if father and mother attributes declared to be not null)
 - OR defer constraint checking



Complex Check Conditions

- The predicate in the check clause can be an arbitrary predicate that can include a subquery.

```
check (time_slot_id in (select time_slot_id from time_slot))
```

The check condition states that the `time_slot_id` in each tuple in the `section` relation is actually the identifier of a time slot in the `time_slot` relation.

- The condition has to be checked not only when a tuple is inserted or modified in `section`, but also when the relation `time_slot` changes



Assertions

- An **assertion** is a predicate expressing a condition that we wish the database **always to satisfy**.
- The following constraints, can be expressed using assertions:
- For each tuple in the *student* relation, the value of the attribute ***tot_cred*** must equal the **sum of credits of courses** that the student has completed successfully.
- An **instructor** cannot teach in two different classrooms in a semester **in the same time slot**
- An assertion in SQL takes the form:
create assertion <assertion-name> check (<predicate>);



Built-in Data Types in SQL

- **date:** Dates, containing a (4 digit) year, month and date
 - Example: `date '2005-7-27'`
- **time:** Time of day, in hours, minutes and seconds.
 - Example: `time '09:00:30'` `time '09:00:30.75'`
- **timestamp:** date plus time of day
 - Example: `timestamp '2005-7-27 09:00:30.75'`
- **interval:** period of time
 - Example: `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



Large-Object Types

- Large objects (photos, videos, CAD files, etc.) are stored as a *large object*.
 - **blob:** binary large object -- object is a large collection of uninterpreted binary data (whose interpretation is left to an application outside of the database system)
 - **clob:** character large object -- object is a large collection of character data
- When a query returns a large object, a pointer is returned rather than the large object itself.



User-Defined Types

- **create type** construct in SQL creates user-defined type

```
create type Dollars as numeric (12,2) final
```

- Example:

```
create table department
(dept_name varchar (20),
building varchar (15),
budget Dollars);
```



Domains

- **create domain** construct in SQL-92 creates user-defined domain types

```
create domain person_name char(20) not null
```

- Types and domains are similar. Domains can have constraints, such as **not null**, specified on them.
- Example:

```
create domain degree_level varchar(10)
```



```
constraint degree_level_test
```

```
check (value in ('Bachelors', 'Masters', 'Doctorate'));
```



Index Creation

- Many queries reference **only a small proportion** of the records in a table.
- It is **inefficient** for the system to read **every record** to find a record with particular value
- An **index** on an attribute of a relation is a **data structure** that allows the database system to find those tuples in the relation that have a specified value for that attribute efficiently, without scanning through all the tuples of the relation.
- We create an index with the **create index** command

```
create index <name> on <relation-name> (attribute);
```



Index Creation Example

- **create table** *student*
(ID varchar (5),
name varchar (20) not null,
dept_name varchar (20),
tot_cred numeric (3,0) default 0,
primary key (ID)
- **create index** *studentID_index* **on** *student*(*ID*)
- The query:

```
select *  
from student  
where ID = '12345'
```

can be executed by **using the index to find the required record, without looking at all records of student**



Authorization

- We may assign a user several forms of authorizations on parts of the database.
 - **Read** - allows reading, but **not modification** of data.
 - **Insert** - allows insertion of new data, but **not modification** of existing data.
 - **Update** - allows modification, **but not deletion of data.**
 - **Delete** - allows deletion of data.
- Each of these types of authorizations is called a **privilege**. We may authorize the user all, none, or a combination of these types of privileges on specified parts of a database, such as a **relation** or a **view**.



Authorization (Cont.)

- Forms of authorization to modify the database schema
 - **Index** - allows creation and deletion of indices.
 - **Resources** - allows creation of new relations.
 - **Alteration** - allows **addition or deletion** of attributes in a relation.
 - **Drop** - allows deletion of relations.



Authorization Specification in SQL

- The **grant** statement is used to confer authorization
 - grant <privilege list> on <relation or view> to <user list>
- <user list> is:
 - a **user-id**
 - **public**, which allows all valid users the privilege granted
 - A **role** (more on this later)
- Example:
 - **grant select on department to Amit, Satoshi**
- Granting a privilege on a **view** does not imply granting any privileges on the **underlying relations**.
- The grantor of the privilege must **already hold** the privilege on the specified item (or be the database administrator).



Privileges in SQL

- **select:** allows read access to relation, or the ability to query using the view
 - Example: grant users U_1 , U_2 , and U_3 **select** authorization on the *instructor* relation:
grant select on instructor to U_1, U_2, U_3
- **insert:** the ability to insert tuples
- **update:** the ability to update using the SQL update statement
- **delete:** the ability to delete tuples.
- **all privileges:** used as a short form for all the allowable privileges



Revoking Authorization in SQL

- The **revoke** statement is used to revoke authorization.

```
revoke <privilege list> on <relation or view> from <user list>
```

- Example:

```
revoke select on student from U1, U2, U3
```

- <privilege-list> may be **all** to revoke all privileges the revoker may hold.
- If <revoker-list> includes **public**, **all users lose** the privilege except those granted it explicitly.
- If the same privilege was granted twice to the same user by different grantees, the user may retain the privilege after the revocation.
- All **privileges that depend on** the privilege being revoked are also **revoked**.



Roles

- A **role** is a way to distinguish among various users as far as what these users can access/update in the database.
- To create a role we use:
create a role <name>
- Example:
 - **create role instructor**
- Once a role is created we can **assign “users” to the role** using:
 - **grant <role> to <users>**



Roles Example

- **create role** instructor;
- **grant** *instructor* **to** Amit;
- Privileges can be granted to roles:
 - **grant select on** *takes* **to** *instructor*,
- Roles can be granted to users, as well as to other roles
 - **create role** *teaching_assistant*
 - **grant** *teaching_assistant* **to** *instructor*,
 - *Instructor* inherits all privileges of *teaching_assistant*
- Chain of roles
 - **create role** *dean*;
 - **grant** *instructor* **to** *dean*;
 - **grant** *dean* **to** Satoshi;



Authorization on Views

- **create view geo_instructor as**
(select *
from instructor
where dept_name = 'Geology');
- **grant select on geo_instructor to geo_staff**
- Suppose that a *geo_staff* member issues
 - **select ***
from geo_instructor,
- What if
 - *geo_staff* does not have permissions on *instructor*?
 - Creator of view did not have some permissions on *instructor*?



Other Authorization Features

- **references** privilege to create foreign key
 - **grant reference** (*dept_name*) **on** *department* **to** Mariano;
 - Why is this required?
- transfer of privileges
 - **grant select** **on** *department* **to** Amit **with grant option**;
 - **revoke select** **on** *department* **from** Amit, Satoshi **cascade**;
 - **revoke select** **on** *department* **from** Amit, Satoshi **restrict**;
 - And more!



End of Chapter 4