Chapter 5 : Intermediate SQL

Database System Concepts, 7th Ed.

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 that requires that tuples in the two relations match (under a specific condition). It also specifies attributes to be 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 of the common columns.
- 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 $A_1, A_2, \ldots A_n$
  from r_1 **natural join** r_2 **natural join .. natural join** r_n
  where P ;

Student Relation

ID	*name*	*dept_name*	*tot_cred*
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

ID	*course_id*	*sec_id*	*semester*	*year*	*grade*
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	*null*

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 the same name get equated incorrectly
- Example -- List the names of students 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*

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

- Relation *prereq*

course_id	*prereq_id*
BIO-301	BIO-101
CS-190	CS-101
CS-347	CS-101

- Observe that

  course information is missing CS-347

  prereq information is missing CS-315

Left Outer Join

- *course* **natural left 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*

- In relational algebra: *course* ⟕ *prereq*

Right Outer Join

- *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

- 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.

Join types
inner join
left outer join
right outer join
full outer join

Join conditions
natural
on <predicate>
using $(A_1, A_2, \ldots, A_n)$

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 and complete actual relations stored in the database.)
- Consider a person who needs to know an instructor's name and department, but not the salary. This person should see a relation, described in SQL, as:

  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 salar

```
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

- **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';
```

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 views**:
- 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** specifications.
  - 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 $10.00 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, …, A_m)
  - The unique specification states that the attributes A_1, A_2, …, 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 specific relation.
- Example: ensure that a 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 of 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 deletion 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**

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>);

Triggers

Triggers

- A **trigger** is a statement that is executed automatically by the system as a side effect of a modification to the database.
- To design a trigger mechanism, we must specify:
  - the conditions under which the trigger is to be executed.
  - the actions to be taken when the trigger executes.
- Triggers introduced to SQL standard in SQL 1999, but supported even earlier using non-standard syntax by most databases.
  - Syntax illustrated here may not work exactly on your database system; check the system manuals

Trigger to Maintain credits_earned value

- **create trigger** *credits_earned* **after update of** *takes* **on** (*grade*)
  referencing new row as *nrow*
  referencing old row as *orow*
  for each row
  when *nrow.grade* <> 'F' **and** *nrow.grade* **is not null**
  and (*orow.grade* = 'F' **or** *orow.grade* **is null**)
  begin atomic
  update *student*
  set *tot_cred= tot_cred +*
  (**select** *credits*
  from *course*
  where *course.course_id= nrow.course_id*)
  where *student.id = nrow.id*;
  end;

Statement Level Triggers

- Instead of executing a separate action for each affected row, a single action can be executed for all rows affected by a transaction
  - Use **for each statement** instead of **for each row**
  - Use **referencing old table** or **referencing new table** to refer to temporary tables (called ***transition tables***) containing the affected rows
  - Can be more efficient when dealing with SQL statements that update a large number of rows

Large-Object Types

- Large objects (photos, videos, CAD files, etc.) are stored as a *large object*:
  - **blob**: binary large object – the 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 – the 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 a 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 tuples in a table.
- It is inefficient for the system to read every tuple to find a tuple with a 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 tuple, without looking at all tuples of *student*

Authorization

- We may assign a user several forms of authorization 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

- 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** U_1, U_2, U_3

- <privilege-list> may be **all** to revoke all privileges.
- If <user-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.

End of Chapter 5