SQL: Aggregation, Joins, and Triggers
CSC 343
Fall 2019

MICHAEL LIUT (MICHAEL.LIUT@UTORONTO.CA)
DEPARTMENT OF MATHEMATICAL AND COMPUTATIONAL SCIENCES
UNIVERSITY OF TORONTO MISSISSAUGA

UNIVERSITY OF TORONTO MISSISSAUGA

UNIVERSITY OF TORONTO MISSISSAUGA

Aggregation Operators

Column values are calculated, and a single value is returned.

SUM, AVG, COUNT, MIN, and MAX.

These operations can be applied on a SELECT clause in a query to produce the aggregation on the column.

e.g. COUNT(*) → counts the number of tuples in a table.

Aggregation Operations are Column Operations!

Example: Aggregation

UNIVERSITY OF TORONTO MISSISSAUGA

From Sells(bar, beer, price) find the average price of Bud.

```
SELECT AVG (price)
FROM   Sells
WHERE beer = 'Bud';
```

UNIVERSITY OF TORONTO MISSISSAUGA

Aggregation Operators

An aggregation operator may not appear in the WHERE clause unless it is in a subquery contained in a HAVING clause or a SELECT list, and the column being aggregated is an outer reference.

An example will shortly follow.

UNIVERSITY OF TORONTO MISSISSAUGA

Duplicates in an Aggregation

To eliminate duplicates use DISTINCT inside an aggregation.

Example: Find the number of ***different*** prices charged for Bud.

```
SELECT   COUNT (DISTINCT price)
FROM     Sells
WHERE    beer = 'Bud';
```

UNIVERSITY OF TORONTO MISSISSAUGA

NULL Values in Aggregation

NULL values are **NEVER** contributed to a SUM, AVG, or COUNT.

NULL values can **NEVER** be the MIN or MAX of a column.

However, if all the values in the column are NULL, then the result of the aggregation is also NULL.

Exception: The COUNT of an empty set is 0.

Example: The NULL Effect

```
SELECT   COUNT(*)
FROM    Sells
WHERE  beer = 'Bud';
```

The number of bars that sell Bud.

```
SELECT   COUNT(price)
FROM    Sells
WHERE  beer = 'Bud';
```

The number of bars that sell Bud at a known price.
i.e. where the price is NOT NULL.

Recall: Sells(bar, beer, price)

Example: A Simple Query

UNIVERSITY OF TORONTO MISSISSAUGA

Find the age of the youngest employee at each rating level.

```
SELECT   MIN(age)
FROM     Employees
WHERE    rating = i;
```

Note: “i” represents a rating value.

Grouping

UNIVERSITY OF TORONTO MISSISSAUGA

We may follow a SELECT-FROM-WHERE expression by GROUP BY and a list of attributes.

The relation that results from the SELECT-FROM-WHERE is grouped according to the values of all those attributes, and any aggregation is applied only within each group.

```
SELECT  rating, MIN(age)
FROM    Employees
GROUP BY rating;
```

Example: Grouping

UNIVERSITY OF TORONTO MISSISSAUGA

Find the average price for each beer from Sells(bar, beer, price)

```
SELECT   beer,  AVG(price)
FROM    Sells
GROUP BY  beer;
```

Result:

beer	AVG(price)
Bud	2.33
Miller	4.55
…	…

UNIVERSITY OF TORONTO MISSISSAUGA

SELECT clause Restrictions with Aggregation

To continue with the paragraph on slide #4:

- If any aggregation is used, then each element of the SELECT list must be either:
  1. Aggregated, or
  2. An attribute on the GROUP BY list.

Example: Grouping

For each drinker, find the average price of Bud at the bars they frequent.
You will use: Sells(bar, beer, price) Frequents(drinker, bar)

Compute all drinker-bar-price triples for 'Bud'.

```
SELECT  drinker,  AVG(price)
FROM    Frequents,  Sells
WHERE beer = 'Bud'  AND  Frequents.bar = Sells.bar
GROUP BY drinker;
```

Then group them by drinker.

Illegal Query Example

UNIVERSITY OF TORONTO MISSISSAUGA

```
SELECT   bar, beer, MIN(price)
FROM    Sells
GROUP BY  bar;
```

This query is illegal in SQL.

There is only one tuple output for each bar. Thus, no unique way to select which beer to output

Illegal Query Example In Detail

UNIVERSITY OF TORONTO MISSISSAUGA

```
SELECT   bar, beer, MIN(price)  AS  minPrice
FROM    Sells
GROUP BY bar;
```

Ideally, we would want to GROUP BY beer.

Sells:

bar	beer	price
Joe	Bud	3.00
Joe	Miller	4.00
Tom	Bud	3.50
Tom	Miller	4.25
Jane	Bud	3.25
Jane	Miller	4.75
Jane	Coors	4.00

Result:

bar	beer	minPrice
Joe	?	3.00
Tom	?	3.50
Jane	?	3.25

{Bud, Miller, Coors}?

Only one tuple output for each bar, no unique way to select which beer to output.

HAVING Clauses

UNIVERSITY OF TORONTO MISSISSAUGA

HAVING <condition> may follow a GROUP BY clause.

If so, the condition applies to each group, and groups not satisfying the condition are eliminated.

Example: Having

From Sells(bar, beer, price) and Beers(name, manf) find the average price of the beers that are either served in at least three bars or are manufactures by Pete's.

```
SELECT   beer,  AVG(price)
FROM    Sells
GROUP BY  beer
HAVING  COUNT(bar) >= 3  OR
beer  IN (  SELECT   name
            FROM    Beers
            WHERE  manf = 'Pete"s'
         );
```

Beer groups with at least 3 non-NULL bars.

Beers manufactured by Pete's.

UNIVERSITY OF TORONTO MISSISSAUGA

Requirements of HAVING Conditions

Anything goes in a subquery.

Outside subqueries, they may refer to attributes only if they are either:

1. A grouping attribute, or
2. Aggregated.

   (same condition as in SELECT clauses with aggregation)

Recall: Aggregation Operations are Column Operations!

UNIVERSITY OF TORONTO MISSISSAUGA

Aggregation Operators

An aggregation operator may not appear in the WHERE clause unless it is in a subquery contained in a HAVING clause or a SELECT list, and the column being aggregated is an outer reference.

```
SELECT  empID, SUM(amount)
FROM    Sales
GROUP BY Employee
HAVING  SUM(amount) > 20000;
```

OR

```
SELECT  empID, SUM(amount)
FROM    Sales
GROUP BY Employee
WHERE empID IN (
      SELECT MAX(empID)
      FROM  Employees);
```

A Final Example

UNIVERSITY OF TORONTO MISSISSAUGA

```
SELECT  bar, SUM(qty) AS sumQ
FROM    Sells
GROUP BY  bar
HAVING SUM(qty) > 4;
```

Sells:

bar	beer	price	qty
Joe	Bud	3.00	2
Joe	Miller	4.00	2
Tom	Bud	3.50	1
Tom	Miller	4.25	4
Jane	Bud	3.25	1
Jane	Miller	4.75	3
Jane	Coors	4.00	2

Result:

bar	sumQ
Tom	5
Jane	6

Cross Product

UNIVERSITY OF TORONTO MISSISSAUGA

A.K.A. Cartesian Product. Denoted by: X

Evaluating joins involves combining two or more relations.

Given two relations, *S* and *R*, each row of *S* is paired with each row of *R*.

Resulting Schema: one attribute from each attribute of *S* and *R*.

Example: Cross Product

Sells:

bar	beer	price
Joe	Bud	3.00
Tom	Miller	4.00
Jane	Lite	3.25

Frequents:

drinker	bar
Aaron	Joe
Mary	Jane

Sells **X** Frequents

(bar)	beer	price	drinker	(bar)
Joe	Bud	3.00	Aaron	Joe
Joe	Bud	3.00	Mary	Jane
Tom	Miller	4.00	Aaron	Joe
Tom	Miller	4.00	Mary	Jane
Jane	Lite	3.25	Aaron	Joe
Jane	Lite	3.25	Mary	Jane

Result:

drinker
Aaron

```
SELECT   drinker
FROM     Frequents, Sells
WHERE    beer = 'Bud' AND Frequents.bar = Sells.bar;
```

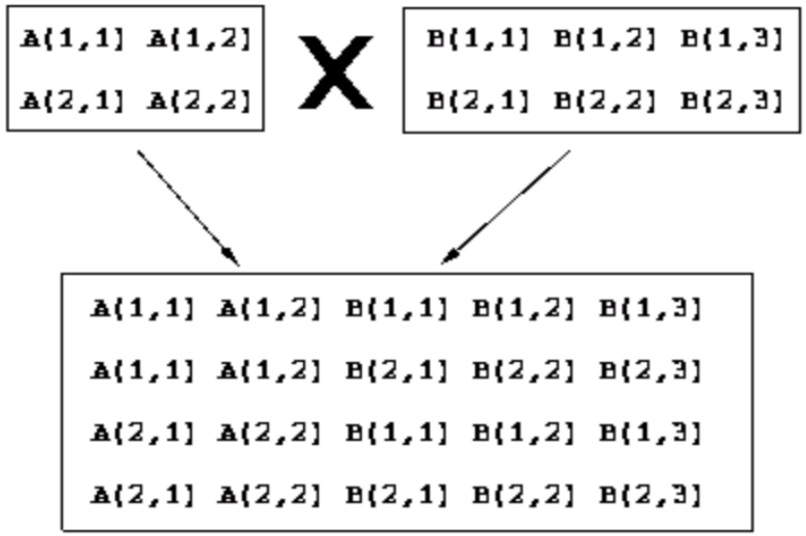
Cross Product

UNIVERSITY OF TORONTO MISSISSAUGA

In general:

	Table A	Table B	A X B
Rows	N	M	N * M
Columns	C	K	C + K

Example: Cross product of 2x2-table **A** and 2x3-table **B**.



Joined Relations

UNIVERSITY OF TORONTO MISSISSAUGA

Join operations take two relations and returns 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.

Example: Join Operations

UNIVERSITY OF TORONTO MISSISSAUGA

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

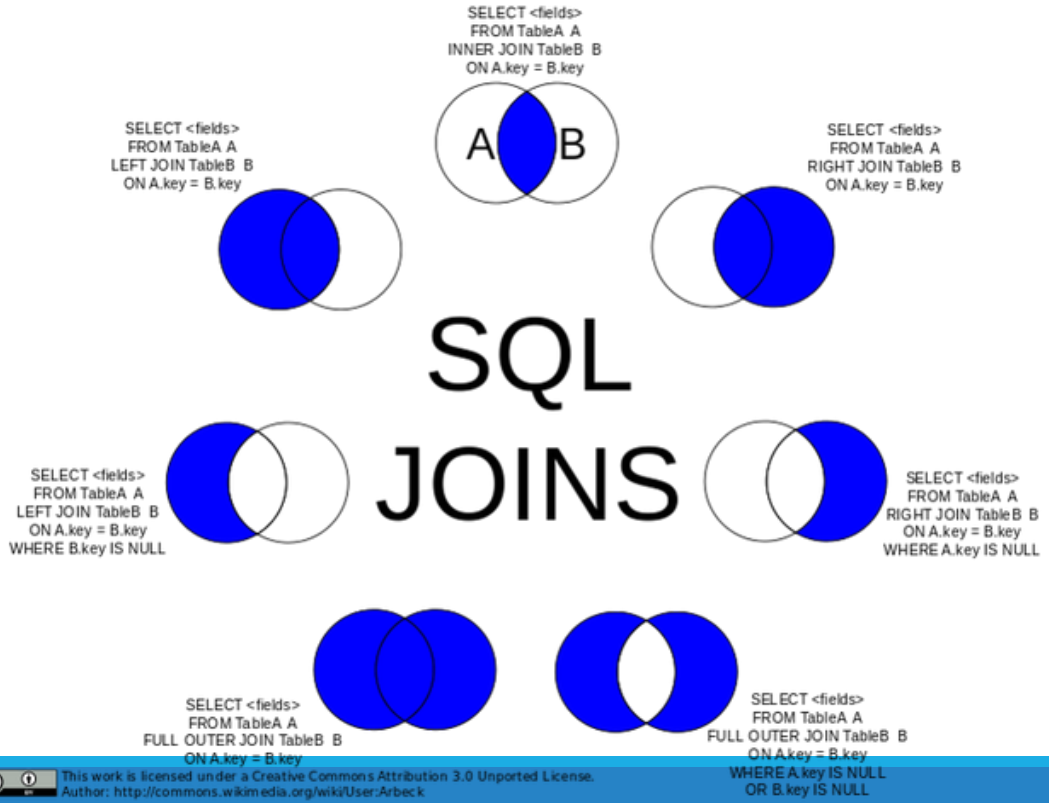
Prereq:

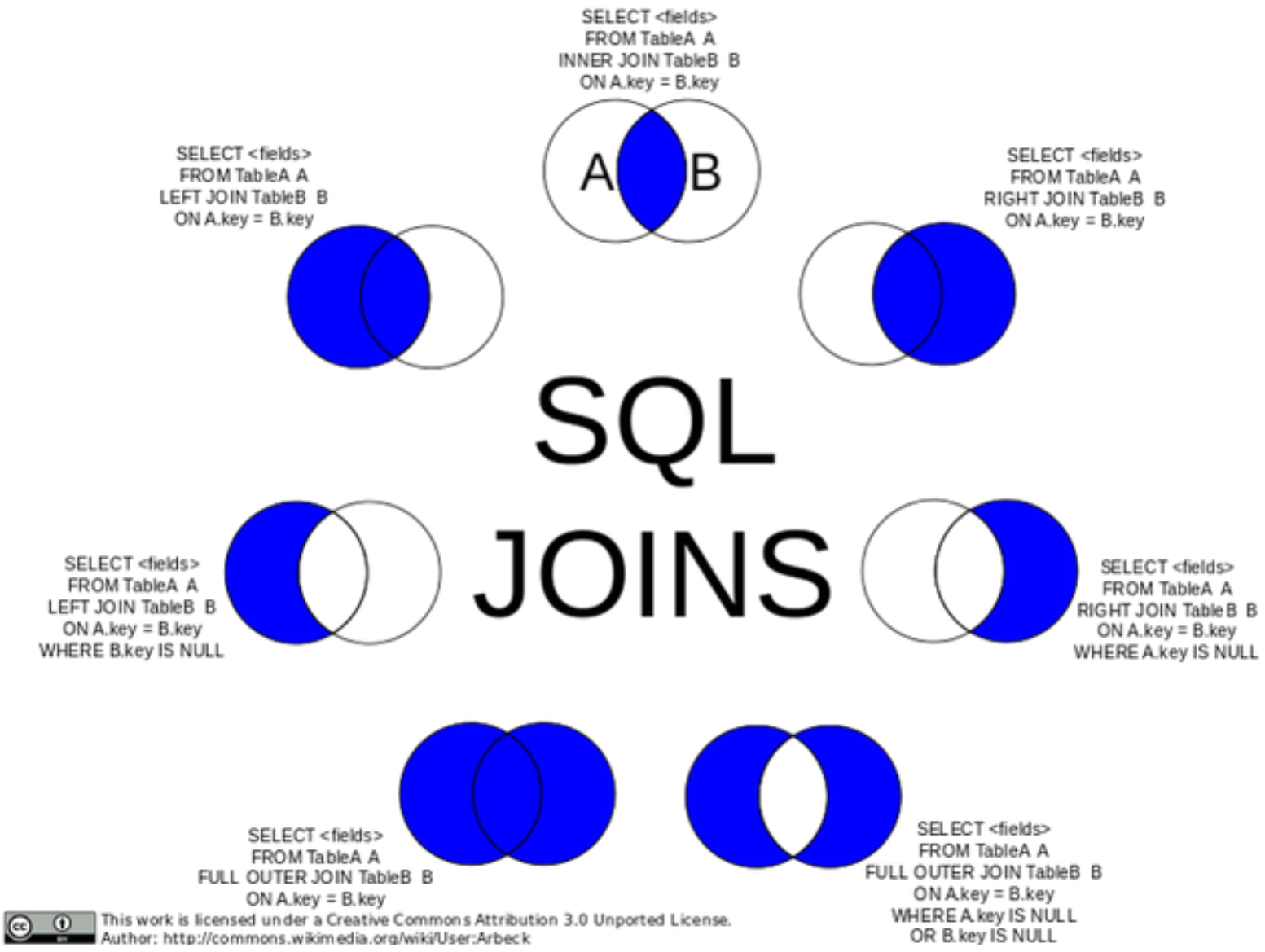
course_id	prereq_id
BIO-301	BIO-101
CS-190	CS-101
CS-347	CS-101

Observe:

1. The prerequisite information is missing for CS-315.
2. The course information is missing for CS-347.

Types of Joins





UNIVERSITY OF TORONTO MISSISSAUGA

Outer Join

An extension of the join operation that avoids loss of information.

Suppose you have two relations *R* and *S*. A tuple of *R* that has no tuple of *S* with which it joins is said to be *dangling*.

- Similarly for a tuple of *S*.

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.

Outerjoin preserves dangling tuples by padding them with NULL.

Left Outer Join

UNIVERSITY OF TORONTO MISSISSAUGA

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

Prereq:

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

Result:

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

Right Outer Join

UNIVERSITY OF TORONTO MISSISSAUGA

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

Prereq:

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

Result:

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

Full Outer Join

UNIVERSITY OF TORONTO MISSISSAUGA

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

Prereq:

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

Result:

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

Inner Join

UNIVERSITY OF TORONTO MISSISSAUGA

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

Prereq:

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

Course **INNER JOIN** Prereq **ON** Course.course_id = Prereq.course_id

Result:

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

UNIVERSITY OF TORONTO MISSISSAUGA

Outer joins

R OUTER JOIN *S* is the core of an outer join expression.

Modified by the following:

1. Optional NATURAL in front of OUTER.
   - Check equality on all common attributes.
   - No two attributes with the same name in the output.
2. Optional ON <condition> after JOIN.
3. Optional LEFT, RIGHT, or FULL in front of OUTER.
   - LEFT = pad dangling tuples of *R* only.
   - RIGHT = pad dangling tuples of *S* only.
   - FULL = pad both; this is the DEFAULT choice.

Example: Outer Join

R:

A	B
1	2
4	5

S:

B	C
2	3
6	7

R **NATURAL FULL OUTER JOIN** S

Result:

A	B	C
1	2	3
4	5	NULL
NULL	6	7

NOTE: (1,2) joins with (2,3), but the other two tuples are dangling!

UNIVERSITY OF TORONTO MISSISSAUGA

Triggers

A procedure that is automatically invoked by the DBMS in response to specified changes to the database.

- Typically invoked by the DBA.

A database that has a set of associated triggers is called an *active database*.

UNIVERSITY OF TORONTO MISSISSAUGA

Triggers

A trigger description contains three parts:

1. Event: a change to the database activates the trigger.
2. Condition: a query or test that is run when the trigger is activated.
3. Action: a procedure that is executed when the trigger is activated and its condition is true.

Triggers

UNIVERSITY OF TORONTO MISSISSAUGA

A trigger can be thought of as a ‘daemon’ which monitors a database, and is executed when the database is modified in a way that matches the event specifications.

i.e. INSERT, UPDATE, and DELETE statements can activate a trigger.

Users are often unaware that a trigger was executes as a side effect of their program.

Daemon

No, not the ancient Greek word that refers to benevolent or benign natural spirits… I am talking about them in the computing sense! ☺

UNIVERSITY OF TORONTO MISSISSAUGA

A computer program that runs as a background process instead of being controlled by an interactive user.

e.g. *SSHD* is the daemon that serves incoming *SSH* connections.

This is seen in computer operating systems, specifically in multitasking.

In UNIX, the parent process of a daemon is usually the *init* process.

Now back to Triggers…

Triggers

A *condition* in a trigger can be a Boolean expression or a query.

e.g. All employees salaries are less than $100,000.

A query is interpreted as TRUE if the answer set is non-empty.

- This invokes the action associated with the trigger.

A query is interpreted as FALSE if it has no answers.

- No action is invoked.

Important Issues Associated With Triggers

UNIVERSITY OF TORONTO MISSISSAUGA

When a trigger *action* executes in a relation, we must specify at what point in the sequence of events it occurs.

- BE CAREFUL!

Depending on what the trigger does, we may want to modify if its action occurs *before* or *after* changes are made to relations.

Important Issues Associated With Triggers

UNIVERSITY OF TORONTO MISSISSAUGA

Example: let's say that we have a statement that INSERTs records into a Student's table.

- This activates a trigger that maintains statistics on how many students younger than 18 years of age are inserted at one time.

Does this trigger happen *before* or *after* the change?

Important Issues Associated With Triggers

UNIVERSITY OF TORONTO MISSISSAUGA

Does this trigger happen *before* or *after* the change?

You have different options, for example:

1. A trigger that initializes a variable used to count the number of qualifying insertions should be executed ***before***.

2. A trigger that executes once ***after*** each record is inserted.
   - Maybe we require the values in the new record to determine the action.

Example: Triggers

UNIVERSITY OF TORONTO MISSISSAUGA

Let's say that we have a statement that INSERTs records into a Student's table.

- This activates a trigger that maintains statistics on how many students younger than 18 years of age are inserted at one time.

Now let's assume that we must examine the age attribute of the Student table to decide whether to increment the count.

- The triggering event here would occur for each modified record.

Example: Triggers

```
CREATE  TRIGGER  init_count  BEFORE INSERT ON Students                /* Event */
        DECLARE
                count  INTEGER;
        BEGIN                                                        /* Action */
                count := 0;
        END


CREATE  TRIGGER  inc_count  AFTER INSERT ON Students                 /* Event */
        WHEN (new.age < 18)                                          /* Condition */
        FOR EACH ROW
        BEGIN                                                        /* Action */
                count := count + 1;
        END
```

"new" is just an inserted tuple.

Note: The init_count trigger is executed once per INSERT, thus FOR EACH ROW was omitted, however, it would be considered a **statement-level** trigger.

Called a **row-level** trigger.

UNIVERSITY OF TORONTO MISSISSAUGA

Row-Level Trigger vs. Statement-Level Trigger

A statement-level trigger is activated once.

A row-level trigger is activated once per iteration of the loop.

e.g. UPDATE attribute

SET columnOne = columnOne +1;

The statement-level trigger will be activated one time (even if no rows are updated).

The row-level trigger will be activated millions of times (dependent on the size/iters).

UNIVERSITY OF TORONTO MISSISSAUGA

Important Note on Triggers

Watch out for chain activations!!!

Depending on your execution of the action, you could potentially activate another trigger. You could potentially even activate the same trigger.

- These are called **recursive triggers**.

Recursive triggers are mostly unpredictable because of the combination of chain activations and order which the DBMS processes this sequence can be difficult to understand.

Constraints vs. Triggers

UNIVERSITY OF TORONTO MISSISSAUGA

Triggers are commonly used to maintain database consistency.

- Must ensure that an Integrity Constraint is not more properly suited.

Constraints are easier to understand as they are not operationally defined.

Constraints prevent inconsistency by any kind of statement.

Constraints afford the opportunity for the DBMS to optimize.

Triggers allow us to impose general (flexible) constraints

Triggers alert users to unusual events (reflected in updates to the database).

Triggers can generate a log of events to support auditing and security checks.

Trigger Flexibility

UNIVERSITY OF TORONTO MISSISSAUGA

Suppose that we have a table called Orders with fields *iternid*, *quantity*, *custornerid*, and *unitprice*. When a customer places an order, the first three field values are filled in by the user (in this example, a sales clerk). The fourth field's value can be obtained from a table called Items, but it is important to include it in the Orders table to have a complete record of the order, in case the price of the item is subsequently changed. We can define a trigger to look up this value and include it in the fourth field of a newly inserted record. In addition to reducing the number of fields that the clerk has to type in, this trigger eliminates the possibility of an entry error leading to an inconsistent price in the Orders table.

Trigger Flexibility

UNIVERSITY OF TORONTO MISSISSAUGA

Continuing with this example, we may want to perform some additional actions when an order is received. For example, if the purchase is being charged to a credit line issued by the company, we may want to check whether the total cost of the purchase is within the current credit limit. We can use a trigger to do the check; indeed, we can even use a CHECK constraint. Using a trigger, however, allows us to implement more sophisticated policies for dealing with purchases that exceed a credit limit. For instance, we may allow purchases that exceed the limit by no more than 10% if the customer has dealt with the company for at least a year, and add the customer to a table of candidates for credit limit increases.

Alert to Unusual Events

UNIVERSITY OF TORONTO MISSISSAUGA

We may want to check if a customer placing an order has made enough purchases in the past month to qualify for an additional discount.

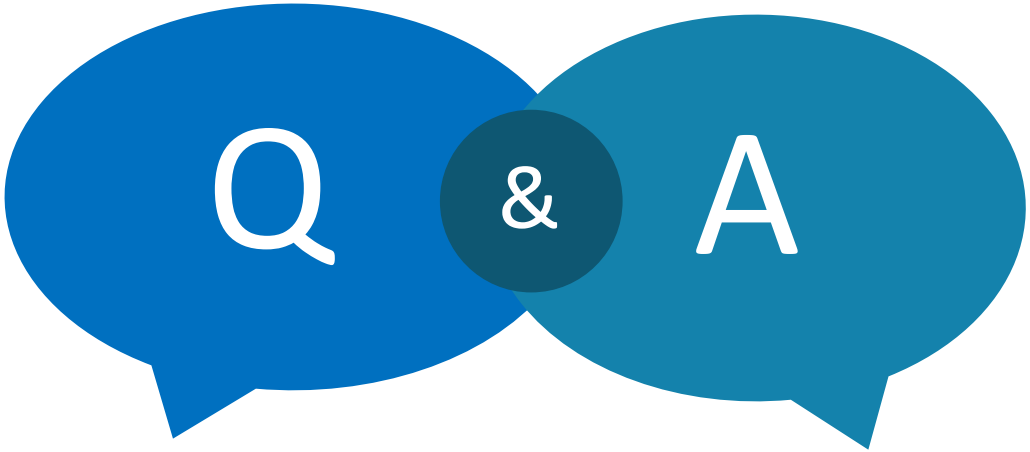
- How? Implement a trigger to check recent purchases and displays message.
- IF TRUE: Inform the Sales Clerk.
- Purpose? To UPSELL or XSELL additional products as they are receiving a discount.

Some Review Questions

UNIVERSITY OF TORONTO MISSISSAUGA

1. What are nested queries? How and when would you use the operators IN, EXISTS, UNIQUE, ANY, and ALL?
2. What are NULL values? Are they supported in the relational model? How do they affect the meaning of queries? Can primary key fields of a table contain NULL values?
3. What is a trigger? What are its 3 parts? What is the difference between a row-level and statement-level trigger?
4. What is grouping? What is its interaction of the HAVING and WHERE clauses? Mention any restrictions that must be satisfies by the fields which appear in the GROUP BY clause.

Questions?



THANKS FOR LISTENING

I'LL BE ANSWERING QUESTIONS NOW

Citations, Images and Resources

UNIVERSITY OF TORONTO MISSISSAUGA

Database Management Systems (3rd Ed.), Ramakrishnan & Gehrke

Some content is based off the slides of Dr. Fei Chiang - http://www.cas.mcmaster.ca/~fchiang/

http://csharpcorner.mindcrackerinc.netdna-cdn.com/UploadFile/BlogImages/06112016031910AM/sql.png

https://lukaseder.files.wordpress.com/2015/10/venn.png?w=662

http://stackoverflow.com/questions/6319183/aggregate-function-in-sql-where-clause

http://www.sql-server-performance.com/2007/aggregate-may-not-appear-in-where-clause/

http://bioinfo.mbb.yale.edu/course/projects/talk-1/db07.html