# CS 4604: Introduction to Database Management Systems

## SQL III

Virginia Tech CS 4604 Sprint 2021

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# Today's Topics

- SQL Statements (Continue)

# More on Set-Comparison Operators

- The comparison condition v > **ALL** V returns TRUE if the value v is greater than all the values in the multiset V.
  - If the nested query doesn't return a value, it evaluates the condition as **TRUE**.
- The comparison condition v > **ANY** V returns TRUE if the value v is greater than at least one value in the multiset V.
  - If the nested query doesn't return a value, it evaluates the whole condition as **FALSE**.

# Queries with ALL/ANY

Q42: Find sailors whose rating is greater than that of *some* sailor called Popeye:

```
SELECT *
FROM   Sailors S
WHERE  S.rating > ANY
        (SELECT  S2.rating
        FROM  Sailors S2
        WHERE
        S2.sname='Popeye')
```

**Sailors**

| sid | sname | rating | age |
|---|---|---|---|
| 1 | Popeye | 10 | 22 |
| 2 | OliveOyl | 11 | 39 |
| 3 | Garfield | 1 | 27 |
| 4 | Bob | 5 | 19 |

# Queries with ALL/ANY

```
SELECT *
FROM   Sailors S
WHERE  S.rating > ALL
        (SELECT  S2.rating
        FROM  Sailors S2)
```

**Sailors**

| sid | sname | rating | age |
|---|---|---|---|
| 1 | Popeye | 10 | 22 |
| 2 | OliveOyl | 11 | 39 |
| 3 | Garfield | 1 | 27 |
| 4 | Bob | 5 | 19 |

# Division

- Relational Division: “Find sailors who’ve reserved all boats.”
  Said differently: “sailors with no counterexample missing boats”

```
SELECT S.sname FROM Sailors S
WHERE NOT EXISTS
   (SELECT B.bid FROM Boats B
   WHERE NOT EXISTS
                    (SELECT R.bid FROM Reserves R
                                          WHERE R.bid=B.bid
   AND R.sid=S.sid ))
```

# What we have so far

- Joins
- Nested Queries
- ALL, ANY, MAX(), etc.

# Example

- Find the sailor with the highest rating

**Sailors**

| sid | sname | rating | age |
|---|---|---|---|
| 1 | Popeye | 10 | 22 |
| 2 | OliveOyl | 11 | 39 |
| 3 | Garfield | 1 | 27 |
| 4 | Bob | 5 | 19 |

# Example

- Find the sailor with the highest rating

```
SELECT
MAX(S.rating)
FROM Sailors S;
```

VS

```
SELECT S.*,
MAX(S.rating)
FROM Sailors S;
```

```
SELECT *
FROM   Sailors S
WHERE  S.rating >= ALL
 (SELECT  S2.rating
 FROM  Sailors S2)
```

VS

```
SELECT *
FROM   Sailors S
WHERE  S.rating =
  (SELECT
  MAX(S2.rating)
  FROM  Sailors S2)
```

```
SELECT *
FROM   Sailors S
ORDER BY rating
DESC
LIMIT 1;
```

# Queries with Subqueries in SELECT/FROM

```
Q46: SELECT P.PRODNR, P.PRODNAME,
     (SELECT SUM(QUANTITY) FROM PO_LINE POL
     WHERE P.PRODNR = POL.PRODNR) AS TOTALORDERED
     FROM PRODUCT P
```

```
Q47: SELECT M.PRODNR, M.MINPRICE, M.MAXPRICE FROM
     (SELECT PRODNR, MIN(PURCHASE_PRICE) AS MINPRICE,
     MAX(PURCHASE_PRICE) AS MAXPRICE
     FROM SUPPLIES GROUP BY PRODNR) AS M
     WHERE M.MAXPRICE-M.MINPRICE > 1
```

# Set Semantics

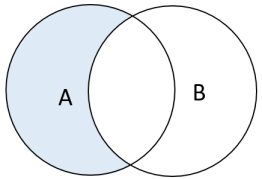
- Set: a collection of distinct elements
- Standard ways of manipulating/combining sets
  - Union
  - Intersect
  - Except
- Treat tuples within a relation as elements of a set

# Default: Set Semantics

- These are relations. They are not sets, since they have duplicates.

R = {A, A, A, A, B, B, C, D}
S = {A, A, B, B, B, C, E}

- UNION
  {A, B, C, D, E}
- INTERSECT
  {A, B, C}
- EXCEPT
  {D}




- A = {10, 5, 25, 30, 45}
- B = {15, 20, 10, 30, 50}
- A UNION B = {5, 10, 15, 20, 25, 30, 45, 50}
- A INTERSECT B = {10, 30}
- A EXCEPT B = {5, 25, 45}

# UNION vs UNION ALL

- The UNION operator is used to combine the result-set of two or more SELECT statements.
  - Each SELECT statement within UNION must have the **same number of columns**
  - The columns must also have similar data types
  - The columns in each SELECT statement must also be in the **same order**
- The UNION operator selects only distinct values by default. To allow duplicate values, use UNION ALL

# Example: UNION ALL

- Sid's of sailors who reserved a red **OR** a green boat

```
SELECT R.sid
FROM Boats B,Reserves R
WHERE R.bid=B.bid AND
      (B.color='red' OR
      B.color='green')
```

```
SELECT R.sid
FROM Boats B, Reserves R
WHERE R.bid=B.bid AND
B.color='red'

UNION ALL

SELECT R.sid
FROM Boats B, Reserves R
WHERE R.bid=B.bid AND
B.color='green'
```

# EXCEPT vs EXCEPT ALL

- The EXCEPT operator returns distinct rows from the first (left) query that are not in the output of the second (right) query
  - The number of columns and their orders must be the same in the two queries
  - The data types of the respective columns must be **compatible**
- With ALL, a row that has m duplicates in the left table and n duplicates in the right table will appear **max(m-n,0)** times in the result set

R = {A, A, A, A, B, B, C, D}  S = {A, A, B, B, B, C, E}

EXCEPT ALL: {A, A, D }

# Example: Except

- Find sailors who have **not** reserved a boat

```
SELECT S.sid
FROM   Sailors S

EXCEPT

SELECT S.sid
FROM   Sailors S, Reserves R
WHERE  S.sid=R.sid
```

# INTERSECT vs INTERSECT ALL

- The INTERSECT operator returns any rows that are available in both result sets
  - The number of columns and their order in the SELECT clauses must be the same
  - The data types of the columns must be compatible
- With ALL, min of cardinalities

R = {A, A, A, A, B, B, C, D}  S = {A, A, B, B, B, C, E}

INTERSECT ALL: {A, A, B, B, C}

# Example: Intersect

- Sid's of sailors who reserved a red **AND** a green boat

```
SELECT R.sid
FROM Boats B, Reserves R
WHERE R.bid=B.bid AND B.color='red'

INTERSECT

SELECT R.sid
FROM Boats B, Reserves R
WHERE R.bid=B.bid AND B.color='green'
```

# Let’s Do Labs

- https://github.com/VTCourses/CS4604_Labs
- Lab3: 3.more_queries

# SQL Views

- SQL views are part of the external data model
- A view is defined by a query over other relations (tables and/or views)
- A view is a **virtual table that does not exist physically**
- A view can be
  - Queried: the query processor replaces the view by its definition.
  - Used in other queries.
- Views allow for logical data independence which makes them a key component in the three-layer database architecture

# Views: Named Queries

```
CREATE VIEW  view_name
AS select_statement
```

```
CREATE VIEW Redcount

AS SELECT B.bid, COUNT(*) AS scount
     FROM Boats B, Reserves R
     WHERE R.bid=B.bid AND B.color='red'
     GROUP BY B.bid
```

# SQL Views

```
CREATE VIEW TOPSUPPLIERS
AS SELECT SUPNR, SUPNAME FROM SUPPLIER
WHERE SUPSTATUS > 50


CREATE VIEW TOPSUPPLIERS_SF
AS SELECT * FROM TOPSUPPLIERS
WHERE SUPCITY = 'San Francisco'
```

# SQL Views

```
CREATE VIEW ORDEROVERVIEW
   (PRODNR, PRODNAME, TOTQUANTITY)
                  AS
    SELECT P.PRODNR, P.PRODNAME, SUM(POL.QUANTITY)
     FROM PRODUCT  AS P
     LEFT OUTER JOIN
     PO_LINE AS POL
            ON (P.PRODNR = POL.PRODNR)
                     GROUP BY P.PRODNR
```

# SQL Views

```
SELECT * FROM TOPSUPPLIERS_SF
SELECT * from redcount;
SELECT * FROM ORDEROVERVIEW WHERE PRODNAME LIKE '%CHARD%'
```

```
SELECT  bname, scount
FROM Boats B,
(SELECT B.bid, COUNT (*)
     FROM Boats B, Reserves R
     WHERE R.bid = B.bid AND
     B.color = 'red'
     GROUP BY B.bid) AS
     Reds(bid, scount)

WHERE  Reds.bid=B.bid
       AND scount < 10
```

**VS**

```
SELECT bname,
scount
FROM Redcount R,
Boats B
WHERE R.bid=B.bid
AND scount < 10;
```

# WITH Queries (Common Table Expressions)

- MySQL 8.0 finally support it

```
WITH Reds(bid, scount) AS
(SELECT B.bid, COUNT (*)
FROM Boats B, Reserves R
WHERE R.bid = B.bid AND
B.color = 'red'
GROUP BY B.bid)
```

```
SELECT bname, scount
FROM Boats B, Reds
WHERE Reds.bid=B.bid
AND scount < 10
```

# WITH Queries (Common Table Expressions)

- Can have many queries in WITH

```
WITH Reds(bid, scount) AS
(SELECT B.bid, COUNT (*)
FROM Boats B, Reserves R
WHERE R.bid = B.bid AND
B.color = 'red'
GROUP BY B.bid),

UnpopularReds AS
(SELECT bname, scount
FROM Boats B, Reds
WHERE Reds.bid=B.bid
AND scount < 10)
```

```
SELECT * FROM UnpopularReds;
```

# ARGMAX GROUP BY

- The sailor with the highest rating per age

```
WITH maxratings(age, maxrating) AS
(SELECT age, max(rating)
FROM Sailors
GROUP BY age)
```

```
SELECT S.*
  FROM Sailors S, maxratings m
 WHERE S.age = m.age
   AND S.rating = m.maxrating;
```

# SQL Views

- Query modification: RDBMS modifies queries that query views into queries on the underlying base tables
- View **materialization**: a physical table is created when the view is first queried
- Unlike a table, a view cannot be updated unless it satisfies certain conditions
  - In this case, the view serves as a window through which updates are propagated to the underlying base table(s)

# SQL Views

```
CREATE VIEW ORDEROVERVIEW(PRODNR, PRODNAME,
TOTQUANTITY)
AS SELECT P.PRODNR, P.PRODNAME, SUM(POL.QUANTITY)
FROM PRODUCT AS P LEFT OUTER JOIN PO_LINE AS POL
ON (P.PRODNR = POL.PRODNR)
GROUP BY P.PRODNR
```

```
UPDATE VIEW ORDEROVERVIEW
SET TOTQUANTITY=10
WHERE PRODNR= '0154'
```

**ERROR!**

# SQL Views

- WITH CHECK option checks UPDATE and INSERT statements for conformity with the view definition

```
CREATE VIEW TOPSUPPLIERS
AS SELECT SUPNR, SUPNAME FROM SUPPLIER
WHERE SUPSTATUS > 50 WITH CHECK OPTION
```

```
UPDATE TOPSUPPLIERS
   SET SUPSTATUS =20
   WHERE SUPNR='32'
```

NOT OK!

```
UPDATE TOPSUPPLIERS
      SET SUPSTATUS =80
     WHERE SUPNR='32'
```

OK!

```
INSERT INTO
TOPSUPPLIERS VALUES(12,
‘new supplier');
```

NOT OK!

# Views and Security

- Views can be used to present necessary information (or a summary), while hiding details in underlying relation(s).
  - Given YoungStudents, but not Students or Enrolled, we can find students who are enrolled, but not the *cid's* of the courses they are enrolled in.

# Delete VIEW

- DROP VIEW TOPSUPPLIERS;
- Like a Symbolic Link: only the view definition is deleted
- delete from viewtest where sid = 11;  ?  **NOT OK!**

# Null Values

- Field values are sometimes unknown
  - SQL provides a special value NULL for such situations.
  - Every data type can be NULL
- The presence of null complicates many issues. E.g.:
  - Selection predicates (WHERE)
  - Aggregation
- But NULLs comes naturally from Outer joins

# NULL in the WHERE clause

- Consider a tuple where rating IS NULL.

```
INSERT INTO sailors VALUES
 (11, 'Jack Sparrow', NULL, 35);
```

```
SELECT * FROM sailors
WHERE rating > 8;
```

Is Jack Sparrow in the output?

# NULL in Comparators

- Rule: (x op NULL) evaluates to … NULL!

```
SELECT 100 = NULL;
SELECT 100 < NULL;
SELECT 100 >= NULL;

  SELECT * FROM sailors WHERE rating IS NULL;

 SELECT * FROM sailors WHERE rating IS NOT NULL;
```

# NULL in Boolean Logic

Three-valued logic:

| NOT | T | F | N |
|---|---|---|---|
| | F | T | N |

| AND | T | F | N |
|---|---|---|---|
| T | T | F | N |
| F | F | F | F |
| N | N | F | N |

| OR | T | F | N |
|---|---|---|---|
| T | T | T | T |
| F | T | F | N |
| N | T | N | N |

**General rule: NULL column values are ignored by aggregate functions**

# NULL and Aggregation

```
SELECT count(*) FROM sailors;

SELECT count(rating) FROM sailors;

SELECT sum(rating) FROM sailors;

SELECT avg(rating) FROM sailors;
```

| sid | sname | rating | age |
|---|---|---|---|
| 1 | Popeye | 10 | 22 |
| 2 | OliveOyl | 11 | 39 |
| 3 | Garfield | 1 | 27 |
| 4 | Bob | 5 | 19 |
| 5 | Jack Sparrow | NULL | 35 |

**General rule: NULL **column values** are ignored by aggregate functions**

# NULLs: Summary

- NULL op NULL is NULL
- WHERE NULL: do not send to output
- Boolean connectives: 3-valued logic
- Aggregates ignore NULL-valued inputs

# SQL Privileges

- A privilege corresponds to the right to use certain SQL statements such as SELECT, INSERT, etc. on one or more database objects

| Privilege | Explanation |
|---|---|
| SELECT | Gives retrieval privilege |
| INSERT | Gives insert privilege |
| UPDATE | Gives update privilege |
| DELETE | Gives delete privilege |
| ALTER | Gives privilege to change the table definition |
| REFERENCES | Gives the privilege to reference the table when specifying integrity constraints |
| ALL | Gives all privileges (DBMS specific) |

# SQL Privileges

```
GRANT SELECT, INSERT, UPDATE, DELETE ON SUPPLIER TO
BBAESENS

GRANT SELECT (PRODNR, PRODNAME) ON PRODUCT TO PUBLIC

REVOKE DELETE ON SUPPLIER FROM BBAESENS

GRANT SELECT, INSERT, UPDATE, DELETE ON PRODUCT TO
WLEMAHIEU WITH GRANT OPTION

GRANT REFERENCES ON SUPPLIER TO SVANDENBROUCKE
```

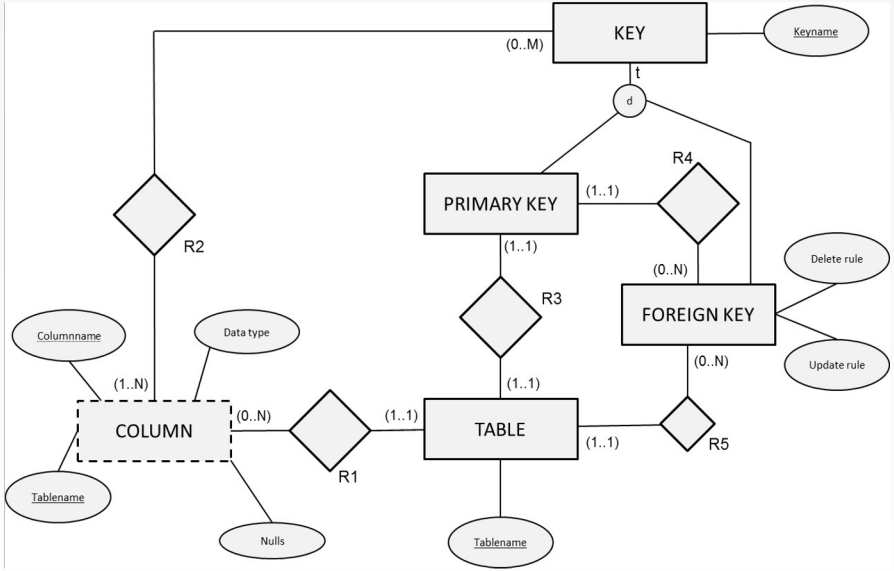
# SQL Privileges

```
CREATE VIEW SUPPLIERS_NY
AS SELECT SUPNR, SUPNAME FROM SUPPLIERS
WHERE SUPCITY = 'New York'


GRANT SELECT ON SUPPLIERS_NY TO WLEMAHIEU
```

# SQL for Metadata Management

- The catalog itself can also be implemented as a relational database



# SQL for Metadata Management

Table(Tablename, …)

Key(Keyname, …)

Primary-Key(*PK-Keyname*, *PK-Tablename*, …)
PK-Keyname is a foreign key referring to Keyname in Key
PK-Tablename is a foreign key referring to Tablename in Table

Foreign-Key(*FK-Keyname*, *FK-Tablename*, *FK-PK-Keyname*, Update-rule, Delete-rule, …)
FK-Keyname is a foreign key referring to Keyname in Key
FK-Tablename is a foreign key referring to Tablename in Table
FK-PK-Keyname is a foreign key referring to PK-Keyname in Primary-Key

Column(Columnname, *C-Tablename*, Data type, Nulls, …)
C-Tablename is a foreign key referring to Tablename in Table

Key-Column(*KC-Keyname, KC-Columnname, KC-Tablename*, …)
KC-Keyname is a foreign key referring to Keyname in Key
KC-Columnname is a foreign key referring to Columnname in Column
KC-Tablename is a foreign key referring to C-Tablename in Column

# SQL for Metadata Management

```
SELECT * FROM INFORMATION_SCHEMA.COLUMNS
WHERE Table_Name = 'SUPPLIER' limit 5;
```

| TABLE_CATALOG (COLUMNS) | TABLE_SCHEMA (COLUMNS) | TABLE_NAME (COLUMNS) | COLUMN_NAME (COLUMNS) | ORDINAL_ (COLUMN |
|---|---|---|---|---|
| def | pgdb___1606131858_5fbba0926751c | supplier | SUPNR | 1 |
| def | pgdb___1606131858_5fbba0926751c | supplier | SUPNAME | 2 |
| def | pgdb___1606131858_5fbba0926751c | supplier | SUPADDRESS | 3 |
| def | pgdb___1606131858_5fbba0926751c | supplier | SUPCITY | 4 |
| def | pgdb___1606131858_5fbba0926751c | supplier | SUPSTATUS | 5 |

# Other SQL Functions

- DATEDIFF()
- ROUND(), Sum(), min(), max(), count()
- IFNULL()
- IF()
- ABS(), avg()
- MOD()
- Between…and
- CASE…WHEN
- A lot more: https://www.w3schools.com/sql/sql_ref_mysql.asp

# Triggers

- A trigger is a stored procedure in database which automatically invokes whenever a special event in the database occurs.
- For example, a trigger can be invoked when a row is inserted into a specified table or when certain table columns are being updated
- Bad triggers: infinite loops...

```
Create trigger zerograde on update takes
(if new takes.grade < 0
then takes.grade = 0)
```

# Assertions

- The assert statement is a useful shorthand for inserting debugging checks
- Verify one or more tables, one or more attributes
- It is in the SQL standard, most DBMS does not support it
- **assert** condition [, message];

```
CREATE ASSERTION FewStudents CHECK (
   (SELECT COUNT(*) FROM Students)
      <=  (SELECT COUNT(*) FROM Courses)
);
```

Can’t have more courses than students

# Tips

- Life is not perfect, so does data
- Generate random data for testing
  - https://mockaroo.com/
- Try to construct data that could check for the following potential errors:
  - Incorrect output schema
  - Output may be missing rows from the correct answer (false negatives)
  - Output may contain incorrect rows (false positives)
  - Output may have the wrong number of duplicates.
  - Output may not be ordered properly.

# Summary

- SQL views
- SQL privileges
- SQL Functions

# Reading and Next Class

- SQL III: Ch 5
- Next: Storing Data and Indexes:
  - Ch 8.1, 8.2
  - Ch 9.1, 9.4
  - Ch 10.3 - 10.8