**ISIT312 Big Data Management**

**Session 2, 2022**

**Exercise-5**

**SQL for Data Warehousing and still more of Hive**

**In this exercise, you will learn how to use Hive HQL extensions for Data Warehousing. A laboratory includes application of SELECT statement with GROUP BY clause, advanced features of GROUP BY clause (ROLLUP, CUBE, GROUPING SETS), windowing and analytics functions.**

***Be careful when copying the Linux commands in this document to your working Terminal, because it is error-prone. Maybe you should type those commands by yourself.***

**Prologue**

Login to your system and start VirtualBox.

When ready start a virtual machine ISIT312-BigDataVM-07-SEP-2020.

**(1) How to start Hadoop, Hive Server 2, beeline or SQL Developer ?**

Open a new Terminal window and start Hadoop in the following way.

$HADOOP\_HOME/sbin/.start-all.sh

When ready minimize the Terminal window used to start Hadoop. We shall refer to this window as to "Hadoop window" and we shall use it later on.

When ready navigate to a folder where you plan to keep your HQL scripts from this lab (you may have to create such folder now) and start Hive Server 2 in the following way.

To start Hive’s metastore service, open ***a Terminal window***, type:

$HIVE\_HOME/bin/hive --service metastore

A message shows that metastore is up and running:

SLF4J: Actual binding is of type [org.apache.logging.slf4j.Log4jLoggerFactory]

To start hiveserver2, open ***another*** ***Terminal window*** and type:

$HIVE\_HOME/bin/hiveserver2

The same message shows that hiveserver2 is up and running.

**[IMPORTANT] Don’t use Zeppelin to run the above two commands, because the %sh interpreter has a timeout threshold.**

You can use Hive’s own interface to interact with Hive. Open another new Terminal window and process the following command.

$HIVE\_HOME/bin/beeline

Process the following command in front of beeline> prompt.

!connect jdbc:hive2://localhost:10000

The statement connects you through JDBC interface to Hive 2 server running on a localhost and listening to a port 10000.

Press Enter when prompted about user name. Press Enter when prompted about password. The system should reply with a prompt

0: jdbc:hive2://localhost:10000>

To find what databases are available process the following command.

show databases;

At the moment only default database is available. We shall create new databases in the future. To find what tables have been created so far process a statement

show tables;

If you plan to use SQL Developer then leftclick at SQL Developer Icon at the top of task bar. Then rightclick at hive connection icon, pick "Connection" option from a menu, enter any user name and password and leftclick at OK button.

We shall use a default database for Hive tables created in this laboratory exercise.

**(2) How to create and how to load data into an internal table ?**

We shall use default database for Hive table created, loaded, and used in this laboratory exercise.

Create the following internal table to store information about items.

create table ORDERS(

part char(7),

customer varchar(30),

amount decimal(8,2),

oyear decimal(4),

omonth decimal(2),

oday decimal(2) )

row format delimited fields terminated by ','

stored as textfile;

The table represents a three-dimensional data cube. A fact entity orders is described by a measure amount. The dimensions include part, customer, and obviously time(oyear,omonth,oday) dimension. There is a hierarchy over time dimension where years consist of months and months consist of days.

Next create a text file items.txt with sample data given below and save a file in a folder where you plan to keep HQL scripts from this lab (you already started Hive Server 2 from this folder).

bolt,James,200,2016,01,01

bolt,Peter,100,2017,01,30

bolt,Bob,300,2018,05,23

screw,James,20,2017,05,11

screw,Alice,55,2018,01,01

nut,Alice,23,2018,03,16

washer,James,45,2016,04,24

washer,Peter,100,2016,05,12

bolt,James,200,2018,01,05

bolt,Peter,100,2018,01,05

To load data into a table orders process the following load statement.

load data local inpath 'items.txt' into table orders;

To verify the contents of a table orders process the following select statement.

select \* from orders;

**(3) How to perform a simple aggregation with group by and having clauses ?**

We start from implementation of a query that *finds the total number of orders per each part*, i.e. we perform aggregation along a dimension part. Create a process the following select statement.

select part, count(\*)

from orders

group by part;

Next, we *find the total number of ordered parts summarized per each part*. It is another aggregation along a dimension part.

select part, sum(amount)

from orders

group by part;

Next, we *find the total number of orders per customer* and we list only the customers who submitted more than one order.

select customer, count(\*)

from orders

group by customer

having count(\*) > 1;

Now, assume that we would like *to find in one query the total number of orders per each part, per each customer and per both part and customer*.

select part, NULL, count(\*)

from orders

group by part

union

select NULL, customer, count(\*)

from orders

group by customer

union

select part, customer, count(\*)

from orders

group by part, customer;

**(4) How to perform aggregations with rollup operator ?**

Assume that we would like to perform aggregation over two dimensions, then over one of the two dimensions used earlier and then aggregation over all orders. For example, *find the total number of parts ordered and summarized per part and per customer, then per part and then total number of all parts ordered*.

select part, customer, sum(amount)

from orders

group by part, customer

union

select part, null, sum(amount)

from orders

group by part

union

select null, null,sum(amount)

from orders;

The same query can be implemented as a single select statement with rollup operator.

select part, customer, sum(amount)

from orders

group by part, customer with rollup;

In the next example we use rollup operator to implement a query that *finds the total number of parts ordered and summarized per year and month, per year, and the total number of parts ordered.*

select oyear, omonth, sum(amount)

from orders

group by oyear,omonth with rollup;

**(5) How to perform aggregation with cube operator ?**

Assume that we would like to *find an average number of parts ordered and summarized per part, per customer, per both part and customer and an average number of parts per order.*

select part, customer, avg(amount)

from orders

group by part, customer with cube;

It is possible to verify some of the results with the following queries.

select avg(amount)

from orders;

and

select part,avg(amount)

from orders

where part='bolt'

group by part;

**(6) How to perform aggregations with grouping sets operator ?**

Assume that we would like to *find the total number of orders per part and per customer and both per year and customer*.

select part, customer, oyear, count(\*)

from ORDERS

group by part, customer, oyear

grouping sets ((part),(customer), (oyear,customer));

In another example we *find the total number of parts ordered and summarized per year, month, day, per year and month , and per year, and the total number of parts ordered*.

SELECT oyear, omonth, oday, sum(amount)

from orders

group by oyear,omonth,oday grouping sets((oyear,omonth,oday),(oyear,omonth), (oyear),() );

**(7) How to perform window based aggregations ?**

It is possible to use group by clause of select statement to find the total number of ordered parts summarized per each part.

select part, sum(amount)

from orders

group by part;

It is possible to get the similar result as from a query with group by clause with so called *windowing*.

select part, SUM(amount) over (partition by part)

from orders;

bolt       900.00  
bolt       900.00  
bolt       900.00  
bolt       900.00  
bolt       900.00  
nut        23.00  
screw      75.00  
screw      75.00  
washer     145.00  
washer     145.00

To get the same results we have to use distinct keyword.

select distinct part, SUM(amount) over (partition by part)

from orders;

bolt       900.00  
nut        23.00  
screw      75.00  
washer     145.00

Now we use windowing to implement a query that *finds for each part, for each customer, and for each amount ordered by customer the largest total number of parts ordered and aggregated per part*.

select part, customer, amount, MAX(amount) over (partition by part)

from orders;

bolt       Peter    100.00    300.00  
bolt       James    200.00    300.00  
bolt       Bob     300.00    300.00  
bolt       Peter    100.00    300.00  
bolt       James    200.00    300.00  
nut        Alice    23.00     23.00  
screw      Alice    55.00     55.00  
screw      James    20.00     55.00  
washer     Peter    100.00    100.00  
washer     James    45.00     100.00

A table orders is partitioned (grouped by) the values in column part and for each part the largest amount is found and added to each output row that consists of part, customer and amount.

It is possible to use more than one aggregation. For example, we extend a query above with the *summarization of the amounts per each part*.

select part, customer, amount,

MAX(amount) over (partition by part),

SUM(amount) over (partition by part)

from orders;

**(7) How to perform window aggregations and window ordering ?**

We start from a query that *finds for each part and amount ordered the total number of parts ordered and summarized per each part*.

select part, amount, SUM(amount) over (partition by part)

from orders;

The results are the following.

bolt 100.00 900.00

bolt 200.00 900.00

bolt 300.00 900.00

bolt 100.00 900.00

bolt 200.00 900.00

nut 23.00 23.00

screw 55.00 75.00

screw 20.00 75.00

washer 100.00 145.00

washer 45.00 145.00

Now, we add a clause order by to *windowing*. Process the following statement.

select part, amount,

SUM(amount) over (partition by part order by amount)

from orders;

bolt 100.00 200.00 |<-- 100+100

bolt 100.00 200.00 |<-- 100+100

bolt 200.00 600.00 |<-- 200+200

bolt 200.00 600.00 |<-- 200+200

bolt 300.00 900.00

nut 23.00 23.00

screw 20.00 20.00

screw 55.00 75.00

washer 45.00 45.00

washer 100.00 145.00

Addition of order by clause computes the increasing results of summarization over the amounts and orders the rows in each partition by the summarized amount. If two rows have the same values of order by amount then the rows are treated as one row with summarized amount. For example the first two rows have the same values of order by amount and because of that a value of SUM(amount) = 100+100. The same applies to the next two rows. If two or more rows have the same values of part and amount then summarization is performed in one step over all such rows. This problem (if it is really a problem ?) can be solved with more selective order by key. For example, the rows in each window can be ordered by amount, oyear, omonth, and oday.

select part,amount,

SUM(amount) over (partition by part

order by amount, oyear, omonth, oday)

from orders;

In this case the rows in each window are ordered by amount, oyear, omonth, oday and summarization is performed in a row-by-row way.

bolt 100.00 100.00

bolt 100.00 200.00

bolt 200.00 400.00

bolt 200.00 600.00

bolt 300.00 900.00

nut 23.00 23.00

screw 20.00 20.00

screw 55.00 75.00

washer 45.00 45.00

washer 100.00 145.00

To *find how the ordered amounts of ordered parts changed year by year* process the following select statement.

select part, amount, oyear,

SUM(amount) over (partition by part order by oyear)

from orders;

bolt       200.00    2016    200.00  
bolt       100.00    2017    300.00  
bolt       100.00    2018    900.00  
bolt       200.00    2018    900.00  
bolt       300.00    2018    900.00  
nut        23.00     2018    23.00  
screw      20.00     2017    20.00  
screw      55.00     2018    75.00  
washer     100.00    2016    145.00  
washer     45.00     2016    145.0

Now, we change aggregation function to AVG.

select part, amount,

AVG(amount) over (partition by part

order by amount, oyear, omonth, oday)

from orders;

The statement finds so called *walking average*.

bolt 100.00 100.000000 AVG(100)

bolt 100.00 100.000000 AVG(100+100)

bolt 200.00 133.333333 AVG(100+100+200)

bolt 200.00 150.000000 AVG(100+100+200+200)

bolt 300.00 180.000000 AVG(100+100+200+200+300)

nut 23.00 23.000000

screw 20.00 20.000000

screw 55.00 37.500000

washer 45.00 45.000000

washer 100.00 72.500000

**(8) How to perform window aggregations and window framing ?**

Next, implement a query that for each part and amount *finds an average of amount ordered by year, month and day.*

select part, amount,

AVG(amount) over (partition by part

order by oyear, omonth, oday)

from orders;

bolt 200.00 200.000000 AVG(200)

bolt 100.00 150.000000 AVG(200+100)

bolt 100.00 150.000000 AVG(200+100)

bolt 200.00 150.000000 AVG(200+100+100+200)

bolt 300.00 180.000000 AVG(200+100+100+200+300)

nut 23.00 23.000000

screw 20.00 20.000000

screw 55.00 37.500000

washer 45.00 45.000000

washer 100.00 72.500000

Processing of aggregation (average) is performed over an expanding frame. At the beginning a *frame* includes the first row, next first row an second row, next first 3 rows, etc.

It is possible to make a frame fixed size and smaller than a window. Process the following statement.

select part, amount,

AVG(amount) over (partition by part

order by oyear, omonth, oday

rows 1 preceding)

from orders;

The statement finds for each part and amount an average amount of the current and previous one amount when the amounts are sorted in time.

bolt 200.00 200.000000 AVG(200)

bolt 100.00 150.000000 AVG(200+100)

bolt 100.00 100.000000 AVG(100+100)

bolt 200.00 150.000000 AVG(100+200)

bolt 300.00 250.000000 AVG(200+300)

nut 23.00 23.000000

screw 20.00 20.000000

screw 55.00 37.500000

washer 45.00 45.000000

washer 100.00 72.500000

Processing of a statement

select part, amount,

AVG(amount) over (partition by part

order by oyear, omonth, oday

rows unbounded preceding)

from orders;

returns the same results as without rows *frame* (the first select statement in this section).

The options of *window framing* are the following.

(ROWS | RANGE) BETWEEN (UNBOUNDED | [num]) PRECEDING AND ([num] PRECEDING | CURRENT ROW | (UNBOUNDED | [num]) FOLLOWING)

For example:

ROWS BETWEEN 3 PRECEDING AND CURRENT ROW,

ROWS BETWEEN UNBOUNDED PRECEDING AND 2 FOLLOWING

(ROWS | RANGE) BETWEEN CURRENT ROW AND (CURRENT ROW | (UNBOUNDED | [num]) FOLLOWING)

For example:

ROWS BETWEEN CURRENT ROW AND UNBOUNDED FOLLOWING

(ROWS | RANGE) BETWEEN [num] FOLLOWING AND (UNBOUNDED | [num]) FOLLOWING

For example:

ROWS BETWEEN 2 FOLLOWING AND UNBOUNDED FOLLOWING

**(9) How to use window clause ?**

It is possible to simplify syntax a bit with window clause (definition). Implement the following query.

select part, SUM(amount) over w

from orders

window w as (partition by part);

**(10) How to use LEAD and LAG functions ?**

LEAD and LAG functions allow to access the previous and the next values in a column. For example, we would like to *find the current and the next amount for each part ordered by year, month, day*.

select part, amount,

LEAD(amount) over (partition by part

order by oyear, omonth,oday)

from orders;

bolt 200.00 100.00

bolt 100.00 100.00

bolt 100.00 200.00

bolt 200.00 300.00

bolt 300.00

nut 23.00

screw 20.00 55.00

screw 55.00

washer 45.00 100.00

washer 100.00

Next, we would like to *find the current and the previous amount for each part ordered by year, month, day*.

select part, amount,

LAG(amount) over (partition by part

order by oyear, omonth, oday)  
from orders;

bolt       200.00      
bolt       100.00    200.00  
bolt       100.00    100.00  
bolt       200.00    100.00  
bolt       300.00    200.00  
nut        23.00      
screw      20.00      
screw      55.00    20.00  
washer     45.00      
washer     100.00    45.00

Next we subtract the previous row value from the current row value.

*s*elect part, amount,

amount-LAG(amount) over(partition by part

order by oyear, omonth, oday)  
from orders;

bolt       200.00      
bolt       100.00    -100.00  
bolt       100.00    0.00  
bolt       200.00    100.00  
bolt       300.00    100.00  
nut        23.00      
screw      20.00      
screw      55.00    35.00  
washer     45.00      
washer     100.00    55.00

Empty places (NULLs) can be eliminated with a parameter 0 in LAG function.

select part, amount,

amount+lag(amount,1,0) over(partition by part

order by oyear, omonth, oday)  
from orders;

bolt       200.00    200.00  
bolt       100.00    300.00  
bolt       100.00    200.00  
bolt       200.00    300.00  
bolt       300.00    500.00  
nut        23.00     23.00  
screw      20.00     20.00  
screw      55.00     75.00  
washer     45.00     45.00  
washer     100.00    145.00

**(11) How to use analytics functions ?**

Finally, we implement windowing with the analytics functions RANK(), DENSE\_RANK(), CUM\_DIST(),

A function RANK() assigns a rank to row such that the rows with the same value of amount are ranked with the same number and rank is increased by the total number of rows with the same value.

select part, amount,

RANK() over (partition by part order by amount)  
from orders;

bolt       100.00    1 RANK=1  
bolt       100.00    1 RANK=1  
bolt       200.00    3 RANK=1+2  
bolt       200.00    3 RANK=1+2  
bolt       300.00    5 RANK=3+2  
nut        23.00     1  
screw      20.00     1  
screw      55.00     2  
washer     45.00     1  
washer     100.00    2

A function DENSE\_RANK() assigns a rank to row such that the rows with the same value of amount are ranked with the same number and rank is increased by 1 for each group of rows with the same value of amount.

select part, amount,

DENSE\_RANK() over (partition by part

order by amount)  
from orders;

bolt       100.00    1  
bolt       100.00    1  
bolt       200.00    2  
bolt       200.00    2  
bolt       300.00    3  
nut        23.00     1  
screw      20.00     1  
screw      55.00     2  
washer     45.00    1  
washer     100.00    2

A function CUME\_DIST() computes the relative position of a specified value in a group of values. For a given row r, the CUME\_DIST()the number of rows with values lower than or equal to the value of r, divided by the number of rows being evaluated, i.e. entire window.

select part, amount,

CUME\_DIST() over (partition by part

order by amount)  
from orders;

bolt       100.00    0.4 2 rows/5  
bolt       100.00    0.4 2 rows/5  
bolt       200.00    0.8 4 rows/5  
bolt       200.00    0.8 4 rows/5  
bolt       300.00    1.0 5 rows/5  
nut        23.00    1.0  
screw      20.00     0.5  
screw      55.00     1.0  
washer     45.00     0.5  
washer     100.00    1.0

A function PERCENT\_RANK() is similar to a function CUME\_DIST(). For a row r, PERCENT\_RANK() calculates the rank of r minus 1, divided by the number of rows being evaluated -1 , i.e. entire window-1.

select part, amount,

PERCENT\_RANK() over (partition by part

order by amount)  
from orders;

bolt       100.00    0.0  
bolt       100.00    0.0  
bolt       200.00    0.5  
bolt       200.00    0.5  
bolt       300.00    1.0  
nut        23.00     0.0  
screw      20.00     0.0  
screw      55.00     1.0  
washer     45.00     0.0  
washer     100.00    1.0

A function NTILE(k) divides a window into a number of buckets indicated by k and assigns the appropriate bucket number to each row. The buckets are numbered from 1 to k.

select part, amount,

NTILE(2) over (partition by part

order by amount)  
from orders;

bolt       100.00    1  
bolt       100.00    1  
bolt       200.00    1  
bolt       200.00    2  
bolt       300.00    2  
nut        23.00    1  
screw      20.00    1  
screw      55.00    2  
washer     45.00    1  
washer     100.00    2

select part, amount,

NTILE(5) over (partition by part

order by amount)  
from orders;

bolt       100.00    1  
bolt       100.00    2  
bolt       200.00    3  
bolt       200.00    4  
bolt       300.00    5  
nut        23.00     1  
screw      20.00    1  
screw      55.00    2  
washer     45.00     1  
washer     100.00    2

Finally, a function ROW\_NUMBER does not need any explanations.

select part, amount,

ROW\_NUMBER() over (partition by part

order by amount)  
from orders;

bolt       100.00    1  
bolt       100.00    2  
bolt       200.00    3  
bolt       200.00    4  
bolt       300.00    5  
nut        23.00     1  
screw      20.00    1  
screw      55.00    2  
washer     45.00    1  
washer     100.00    2

*End of Exercise 5*