Advanced Data Management Technologies

Unit 10 — SQL GROUP BY Extensions

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Outline

1. **SQL OLAP Extensions**
2. **GROUP BY Extensions**
   - ROLLUP
   - CUBE
   - GROUPING SETS
   - GROUPING
   - GROUPING_ID

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   - ROLLUP
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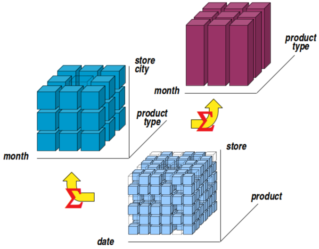
   - GROUPING_ID

SQL Extensions for OLAP

- A key concept of OLAP systems is multidimensional analysis: examining data from many dimensions.
- Examples of multidimensional requests:
  - Show total sales across all products at increasing aggregation levels for a geography dimension, from state to country to region, for 1999 and 2000.
  - Create a cross-tabular analysis of our operations showing expenses by territory in South America for 1999 and 2000. Include all possible subtotals.
  - List the top 10 sales representatives in Asia according to 2000 sales revenue for food products, and rank their commissions.



- We use the ISO SQL:2003 OLAP extensions for our illustrations.

Overview

- We discuss how SQL:2003 has extended SQL-92 to support OLAP queries.
  - Crosstab
  - GROUP BY extensions
    - ROLLUP, CUBE, GROUPING SETS
    - Hierarchical cube
  - Analytic funtions
    - Ranking and percentiles
    - Reporting
    - Windowing
  - Data densification (partitioned outer join)

Crosstab/1

- Cross-tabular report with (sub)totals

	Country		
Media	**France**	**USA**	**Total**
Internet	9,597	124,224	133,821
Sales	61,202	638,201	699,403
Total	70,799	762,425	833,224

- This is space efficient for dense data only (thus, few dimensions).
- Shows data at four different “granularities”.

Crosstab/2

- Tabular representation for the cross-tabular report with totals.
- ALL is a dummy value and stands for all or multiple values.
- Probably not as nice to read as the crosstab.
- Information content is the same as in the crosstab.
- Is more space efficient than crosstab if the data is sparse.
- Compatible with relational DB technology.

Media	Country	Total
Internet	France	9,597
Internet	USA	133,821
Direct Sales	France	61,202
Direct Sales	USA	638,201
Internet	ALL	133,821
Direct Sales	ALL	699,403
ALL	France	70,799
ALL	USA	762,425
ALL	ALL	833,224

Outline

GROUP BY Extensions/1

- Aggregation is a fundamental part of OLAP and data warehousing.
- Oracle provides the following extensions to the GROUP BY clause:
  - CUBE and ROLLUP
  - GROUPING SETS expression
  - GROUPING functions
- The CUBE, ROLLUP, and GROUPING SETS extensions
  - make querying and reporting easier and faster, and
  - produce a single result set that is equivalent to a UNION ALL of differently grouped rows.
- GROUPING functions allow to identify the roll-up (grouping) level

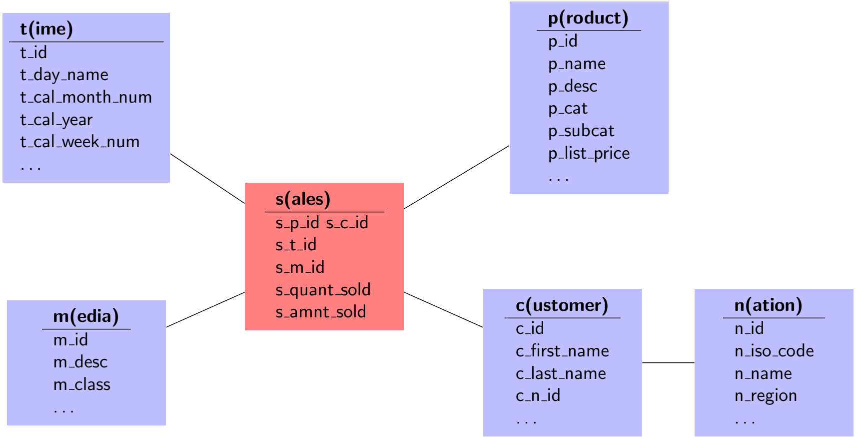
GROUP BY Extensions/2

- **ROLLUP** calculates aggregations such as SUM, COUNT, MAX, MIN, and AVG at increasing levels of aggregation, from the most detailed up to a grand total.
- **CUBE** is similar to ROLLUP, enabling a single statement to calculate all possible combinations of aggregations.
  - Computing a CUBE creates a heavy processing load!
- The **GROUPING SETS** extension lets you specify just the needed groupings in the GROUP BY clause.
  - This allows efficient analysis across multiple dimensions without performing a CUBE operation.
  - Replacing cubes with grouping sets can significantly increase performance.

Syntax of GROUP BY Extensions

- `GROUP BY ROLLUP(gcols)`
  - Roll-up hierarchically
- `GROUP BY CUBE(gcols)`
  - Roll-up to all possible combinations
- `GROUP BY gcols_1, CUBE(gcols_2)`
  - Partial roll-up
- `GROUP BY GROUPING SETS (gcols_1, ..., gcols_n)`
  - Explicit specification of roll-ups
- `GROUP BY groupings_1, groupings_2, ...`
  - Cross-product of groupings
- `SELECT ... GROUPING_ID(gcols) ...`
  - Identification of roll-up level

Example Sales Schema/1



Example Sales Schema/2

- An instance is in Oracle DB on `dukefleet.inf.unibz.it`
  - Available in schema `bi`
  - Write `bi.s` to access the sales table
- The following view `bi.tpch` is available

```
CREATE OR REPLACE VIEW bi.tpch AS
SELECT *
FROM   bi.s, bi.p, bi.c, bi.t, bi.m, bi.n
WHERE  s_t_id = t_id
AND    s_p_id = p_id
AND    s_c_id = c_id
AND    s_m_id = m_id
AND    c_n_id = n_id;
```

Querying Sales Schema/3

- To access the DB with sqlplus, log in to students.inf.unibz.it (or russel.inf.unibz.it)
  - SQL*Plus is the most basic Oracle Database utility, with a basic command-line interface, commonly used by users, administrators, and programmers.
  - Works also from your notebook if an sqlplus client is installed
- Create a text file with SQL commands, e.g., q1.sql:

```
-- This is an example file.  A semicolon terminates a statement.
-- desc x describes the schema of table x.
-- Comment lines start with two -'s
select count(*) from bi.s;
desc bi.s;
quit;
```

- Execute the file by running the command:

```
sqlplus admt/dummy@dukefleet.inf.unibz.it:1521/duke.inf.unibz.it @q1
```

- Start sqlplus for a dialog:

```
rlwrap sqlplus admt/dummy@dukefleet.inf.unibz.it:1521/duke.inf.unibz.it
```

ROLLUP Example/1

```
SELECT    m_desc, t_cal_month_desc, n_iso_code, SUM(s_amount_sold)
FROM      bi.tpch
WHERE     m_desc IN ('Direct Sales', 'Internet')
AND       t_cal_month_desc IN ('2000-09', '2000-10')
AND       n_iso_code IN ('GB', 'US')
GROUP BY ROLLUP(m_desc, t_cal_month_desc, n_iso_code);
```

- Rollup from right to left.
- Computes and combines the following 4 groupings:
  - m_desc, t_cal_month_desc, n_iso_code
  - m_desc, t_cal_month_desc
  - m_desc
  - -
- Note that the actual number of result tuples (i.e., groups) is typically different and depends on the number of different values of the grouping attributes.

ROLLUP Example/2

M_DESC	T_CAL_MO	N_	SUM(S_amount_sold)
Internet	2000-09	GB	16569.36
Internet	2000-09	US	124223.75
Internet	2000-10	GB	14539.14
Internet	2000-10	US	137054.29
Direct Sales	2000-09	GB	85222.92
Direct Sales	2000-09	US	638200.81
Direct Sales	2000-10	GB	91925.43
Direct Sales	2000-10	US	682296.59
Internet	2000-09		140793.11
Internet	2000-10		151593.43
Direct Sales	2000-10		774222.02
Direct Sales	2000-09		723423.73
Internet			292386.54
Direct Sales			1497645.75
			1790032.29

Partial ROLLUP Example/1

```
SELECT   m_desc, t_cal_month_desc, n_iso_code, SUM(s_amount_sold)
FROM     bi.tpch
WHERE    m_desc IN ('Direct Sales', 'Internet')
AND      t_cal_month_desc IN ('2000-09', '2000-10')
AND      n_iso_code IN ('GB', 'US')
GROUP BY m_desc, ROLLUP(t_cal_month_desc, n_iso_code);
```

- m_desc is always present and not part of the rollup hierarchy.
- Computes and combines the following groupings:
  - m_desc, t_cal_month_desc, n_iso_code
  - m_desc, t_cal_month_desc
  - m_desc

Partial ROLLUP Example/2

M_DESC	T_CAL_MO	N_	SUM(S_amount_sold)
Internet	2000-09	GB	16569.36
Internet	2000-09	US	124223.75
Internet	2000-10	GB	14539.14
Internet	2000-10	US	137054.29
Direct Sales	2000-09	GB	85222.92
Direct Sales	2000-09	US	638200.81
Direct Sales	2000-10	GB	91925.43
Direct Sales	2000-10	US	682296.59
Internet	2000-09		140793.11
Internet	2000-10		151593.43
Direct Sales	2000-10		774222.02
Direct Sales	2000-09		723423.73
Internet			292386.54
Direct Sales			1497645.75

ROLLUP

- `ROLLUP` creates subtotals at $n+1$ levels (i.e., $n+1$ groupings), where n is the number of grouping columns.
  - Rows that would be produced by `GROUP BY` without `ROLLUP`
  - First-level subtotals
  - Second-level subtotals
  - ...
  - A grand total row
- It is very helpful for subtotaling along a hierarchical dimensions such as time or geography.
  - `ROLLUP(y, m, day)`
  - `ROLLUP(country, state, city)`

CUBE Example/1

```
SELECT    m_desc, t_cal_month_desc, n_iso_code, SUM(s_amount_sold)
FROM      bi.tpch
WHERE     m_desc IN ('Direct Sales', 'Internet')
AND       t_cal_month_desc IN ('2000-09', '2000-10')
AND       n_iso_code IN ('GB', 'US')
GROUP BY CUBE(m_desc, t_cal_month_desc, n_iso_code);
```

- Produces all possible roll-up combinations.
  - m_desc, t_cal_month_desc, n_iso_code
  - m_desc, t_cal_month_desc
  - m_desc, n_iso_code
  - t_cal_month, n_iso_code
  - m_desc
  - t_cal_month_desc
  - n_iso_code
  - -

CUBE Example/2

M_DESC	T_CAL_MO	N_	SUM(S_AMOUNT_SOLD)
Internet	2000-09	GB	16569.36
Internet	2000-09	US	124223.75
Internet	2000-10	GB	14539.14
Internet	2000-10	US	137054.29
Direct Sales	2000-09	GB	85222.92
Direct Sales	2000-09	US	638200.81
Direct Sales	2000-10	GB	91925.43
Direct Sales	2000-10	US	682296.59
	2000-09	GB	101792.28
	2000-09	US	762424.56
	2000-10	GB	106464.57
	2000-10	US	819350.88
Internet		GB	31108.50
Internet		US	261278.04
Direct Sales		GB	177148.35
Direct Sales		US	1320497.4
Internet	2000-09		140793.11
Internet	2000-10		151593.43
Direct Sales	2000-09		723423.73
Direct Sales	2000-10		774222.02
Internet			292386.54
Direct Sales			1497645.75
	2000-09		864216.84
	2000-10		925815.45
		GB	208256.85
		US	1581775.44
			1790032.29

CUBE

- CUBE creates 2^n combinations of subtotals (i.e., groupings), where n is the number of grouping columns.
- Includes all the rows produced by `ROLLUP`.
- `CUBE` is typically most suitable in queries that use columns from multiple dimensions rather than columns representing different levels of a single dimension.
  - e.g., subtotals for all combinations of month, state, and product.
- Partial `CUBE` similar to partial `ROLLUP`.

GROUPING SETS Example/1

```
SELECT   m_desc, t_cal_month_desc, n_iso_code, SUM(s_amount_sold)
FROM     bi.tpch
WHERE    m_desc IN ('Direct Sales', 'Internet')
AND      t_cal_month_desc IN ('2000-09', '2000-10')
AND      n_iso_code IN ('GB', 'US')
GROUP BY GROUPING SETS ((m_desc, t_cal_month_desc, n_iso_code),
                        (m_desc, n_iso_code),
                        (t_cal_month_desc, n_iso_code));
```

- GROUPING SETS produce just the specified groupings.
- No (automatic) rollup is performed.

GROUPING SETS Example/2

M_DESC	T_CAL_MO	N_	SUM(S_AMOUNT_SOLD)
Internet	2000-09	GB	16569.36
Direct Sales	2000-09	GB	85222.92
Internet	2000-09	US	124223.75
Direct Sales	2000-09	US	638200.81
Internet	2000-10	GB	14539.14
Direct Sales	2000-10	GB	91925.43
Internet	2000-10	US	137054.29
Direct Sales	2000-10	US	682296.59
	2000-09	GB	101792.28
	2000-09	US	762424.56
	2000-10	GB	106464.57
	2000-10	US	819350.88
Internet		GB	31108.5
Internet		US	261278.04
Direct Sales		GB	177148.35
Direct Sales		US	1320497.4

Equivalences

- `CUBE(a,b)` ≡ `GROUPING SETS ((a,b), (a), (b), ())`
- `ROLLUP(a,b,c)` ≡ `GROUPING SETS ((a,b,c), (a,b), (a), ())`
- `GROUP BY GROUPING SETS(a,b,c)`
  ≡ `GROUP BY a UNION ALL GROUP BY b UNION ALL GROUP BY c`
- `GROUP BY GROUPING SETS((a,b,c))` ≡ `GROUP BY a, b, c`
- `GROUP BY GROUPING SETS(a,b,(b,c))`
  ≡ `GROUP BY a UNION ALL GROUP BY b UNION ALL GROUP BY b, c`
- `GROUP BY GROUPING SETS(a,ROLLUP(b,c))`
  ≡ `GROUP BY a UNION ALL GROUP BY ROLLUP(b, c)`

Identification of Groupings

- Two challenges arise with the use of `ROLLUP` and `CUBE`:
  1. How to programmatically determine which rows in the result set are subtotals?
  2. How to find the exact level of aggregation for a given subtotal?
- Subtotals are often needed to calculate percent-of-totals.
- Distinction between NULL values created by `ROLLUP` or `CUBE` and NULL values stored in the data is often important.
- SQL provides functions for this:
  - `GROUPING`
  - `GROUPING_ID`

GROUPING Function Example/1

```
SELECT   m_desc, t_cal_month_desc, n_iso_code, SUM(s_amount_sold)
         GROUPING(m_desc) AS M,
         GROUPING(t_cal_month_desc) AS T,
         GROUPING(n_iso_code) AS N
FROM     bi.tpch
WHERE    m_desc IN ('Direct Sales', 'Internet')
AND      t_cal_month_desc in ('2000-09', '2000-10')
AND      n_iso_code IN ('GB', 'US')
GROUP BY ROLLUP(m_desc, t_cal_month_desc,n_iso_code);
```

- **GROUPING** has a single column as argument and returns
  - 1 when it encounters a NULL value created by a ROLLUP or CUBE operation;
    - NULL indicates that the row is a subtotal
  - 0 for any other type of value, including a stored NULL value.

GROUPING Function Example/2

M_DESC	T_CAL_MO	N_	SUM(S_amount_sold)	M	T	N
Internet	2000-09	GB	16569.36	0	0	0
Internet	2000-09	US	124223.75	0	0	0
Internet	2000-10	GB	14539.14	0	0	0
Internet	2000-10	US	137054.29	0	0	0
Direct Sales	2000-09	GB	85222.92	0	0	0
Direct Sales	2000-09	US	638200.81	0	0	0
Direct Sales	2000-10	GB	91925.43	0	0	0
Direct Sales	2000-10	US	682296.59	0	0	0
Internet	2000-09		140793.11	0	0	1
Internet	2000-10		151593.43	0	0	1
Direct Sales	2000-10		774222.02	0	0	1
Direct Sales	2000-09		723423.73	0	0	1
Internet			292386.54	0	1	1
Direct Sales			1497645.75	0	1	1
			1790032.29	1	1	1

- Detail rows have '0 0 0', first level subtotals '0 0 1', second level subtotals '0 1 1', and overall total '1 1 1'.

GROUPING_ID

- To find the GROUP BY level of a row, a query must return the GROUPING function information for each GROUP BY column.
  - Inconvenient and long SQL code
  - Extra storage space if stored
- The GROUPING_ID function addresses this problem.
  - GROUPING_ID takes a list of grouping columns as an argument.
  - For each column it returns 1 if its value is NULL because of a ROLLUP or CUBE, and 0 otherwise.
  - The list of binary digits is interpreted as a binary number and returned as a base-10 number.

- **Example:** GROUPING_ID(a,b) for CUBE(a,b)

a	b	Bit vector	GROUPING_ID(a,b)
1	2	0 0	0
1	NULL	0 1	1
NULL	1	1 0	2
NULL	NULL	1 1	3

GROUPING_ID Example/1

```
SELECT   CASE WHEN GROUPING_ID(m_desc)=1 THEN '*' ELSE m_desc END,
         CASE WHEN GROUPING_ID(n_iso_c)=1 THEN '*' ELSE n_iso_c END,
         SUM(s_amount_sold),
         GROUPING_ID(m_desc, n_iso_code) AS MN
FROM     bi.tpch
WHERE    m_desc IN ('Direct Sales', 'Internet')
AND      t_cal_month_desc= '2000-09'
AND      n_iso_code IN ('GB', 'US')
GROUP BY CUBE(m_desc, n_iso_code);
```

- Replaces all NULL from rollup with string '*'.
- Leaves NULL that are not the result of rollup untouched.
- Could easily make selective replacements of NULL.

GROUPING_ID Example/2

CASEWHENGROUPING(M_D	CAS	SUM(S_AMOUNT_SOLD)	MN
Internet	GB	16569.36	0
Internet	US	124223.75	0
Direct Sales	GB	85222.92	0
Direct Sales	US	638200.81	0
Direct Sales	*	723423.73	1
Internet	*	140793.11	1
*	GB	101792.28	2
*	US	762424.56	2
*	*	864216.84	3

Composite Columns

- A **composite column** is a collection of columns that are treated as a unit for the grouping.
- Allows to skip aggregation across certain levels.

- **Example:** `ROLLUP(year,(quarter,month),day)`
  - `(quarter,month)` is treated as a unit.
  - Produces the following groupings:
    ```
    (year,quarter,month,day)
    (year,quarter,month)
    (year)
    ()
    ```

Concatenated Groupings

- A **concatenated grouping** is specified by listing multiple grouping sets, cubes, and rollups, and produces the cross-product of groupings from each grouping set.
- **Example:**
  `GROUP BY GROUPING SETS((a),(b)), GROUPING SETS((c),(d))`
  - Produces the groupings (a,c), (a,d), (b,c), (b,d)
- A concise and easy way to generate useful combinations of groupings.
- A small number of concatenated groupings can generate a large number of final groups.
- One of the most important uses for concatenated groupings is to generate the aggregates for a hierarchical cube.

Hierarchical Cubes/1

- A **hierarchical cube** is a data set where the data is aggregated along the rollup hierarchy of each of its dimensions.
- The aggregations are combined across dimensions.

- **Example:** Hierarchical cube across 3 dimensions

```
GROUP BY ROLLUP(year, quarter, month),
         ROLLUP(category,subcategory,name),
         ROLLUP(region,subregion,country,state,city)
```

  - Groupings: `(year,category,region)`, `(year,quarter,category,region)`, `(year,quarter,month,category,region)`, ...
  - Produces a total of $4 \cdot 4 \cdot 6 = 96$ groupings.
  - Compare to $2^{11} = 2048$ groupings by `CUBE` and 96 explicit group specifications.

- In SQL we specify hierarchies explicitly. They are not "known" to the system.

Hierarchical Cubes/2

- Hierarchical cubes form the basis for many analytic applications, but frequently only certain slices are needed.
- Complex OLAP queries are handled by enclosing the hierarchical cube in an outer query that specifies the exact slice that is needed.

```
SELECT month, division, sum_sales
FROM   ( SELECT   year, quarter, month, division, brand, item
                  SUM(sales) sum_sales,
                  GROUPING_ID(grouping_columns) gid
         FROM     sales, products, time
         GROUP BY ROLLUP(year, quarter, month),
                  ROLLUP(division, brand, item)
       )
WHERE  division = 25
AND    month = 2002-01
AND    gid = 3; -- grouping by month and division
```

- Bit vector for grouping by month and division: 0 0 0 0 1 1

Hierarchical Cubes/3

- Query optimizers are tuned to efficiently handle nested hierarchical cubes.
- Based on the outer query condition, unnecessary groups are not generated.
  - In the example, 15 out of 16 groupings are removed (i.e., all groupings involving year, quarter, brand, and item)
- Optimized query:

```
SELECT month, division, sum_sales
FROM   ( SELECT   year, quarter, month, division, null, null
                  SUM(sales) sum_sales,
                  GROUPING_ID(grouping_columns) gid
         FROM     sales, products, time
         GROUP BY year, quarter, month, division
       )
WHERE  division = 25
AND    month = 2002-01
AND    gid = gid-for-Division-Month;
```

Summary

- ISO SQL:2003 has added a lot of support for OLAP operations.
  - This was triggered by intensive DW research during the last 1-2 decades.
- Grouping and aggregation is a major part of SQL.
- OLAP extensions of `GROUP BY` clause since SQL:2003
  - `ROLLUP, CUBE, GROUPING SETS` are compact ways to express different groupings over the grouping attributes
    - `ROLLUP` generates results at $n+1$ increasing levels of aggregation
    - `CUBE` generates results for all 2^n possible combinations of the grouping attributes
    - `GROUPING SETS` generates results exactly for the specified groupings
  - Composite columns allow to skip certain levels of aggregation
  - Concatenated groupings build the cross-product of a list of specified groupings (by ROLLUP, CUBE, etc.)
  - `GROUPING` and `GROUPING_ID` allow to programmatically identify groupings
- There exist a number of equivalence rules between the different forms of groupings.