ETL and OLAP Systems

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Review of the Previous Lecture

- Mining of massive datasets.
- Evolution of database systems.
- Dimensional modeling:
  - Three goals of the logical design of data warehouse: **simplicity**, **expressiveness** and **performance**.
  - The most popular conceptual schema: **star schema**.
  - Designing data warehouses is not an easy task . . .

Outline

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  - Map-reduce-based languages.

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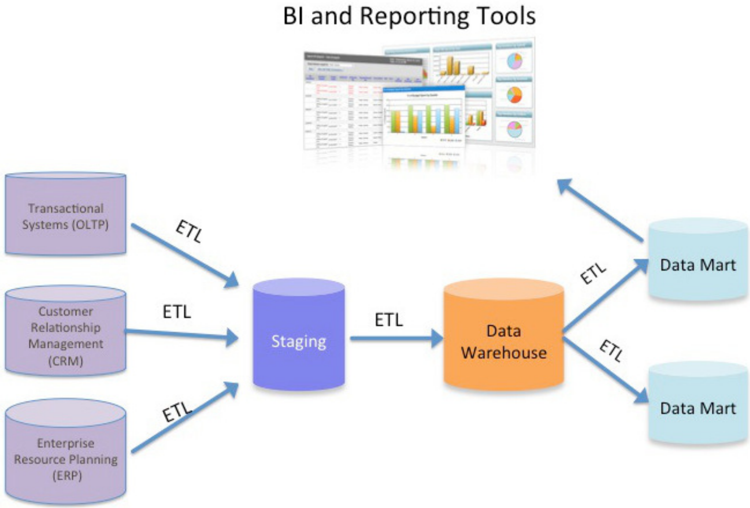
- **ETL** = Extraction, Transformation, and Load
  - **Extraction** of data from source systems,
  - **Transformation** and **integration** of data into a useful format for analysis,
  - **Load** of data into the warehouse and build of additional structures.
- **Refreshment** of data warehouse is closely related to ETL process.
- The ETL process is described by metadata stored in data warehouse.
- Architecture of data warehousing:

  Data sources $\Rightarrow$ Data staging area $\Rightarrow$ Data warehouse

ETL



BI and Reporting Tools
Transactional Systems (OLTP)
Customer Relationship Management (CRM)
Enterprise Resource Planning (ERP)
ETL
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Staging
ETL
Data Warehouse
ETL
ETL
Data Mart
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Tools for ETL

- Data extraction from heterogeneous data sources.
- Data transformation, integration, and cleansing.
- Data quality analysis and control.
- Data loading.
- High-speed data transfer.
- Data refreshment.
- Managing and analyzing metadata.
- **Examples of ETL tools**:
  - MS SQL Server Integration Services(SSIS), IBM Infosphere DataStage, SAS ETL Studio, Oracle Warehouse Builder, Oracle Data Integrator, Business Objects Data Integrator, Pentaho Data Integration.

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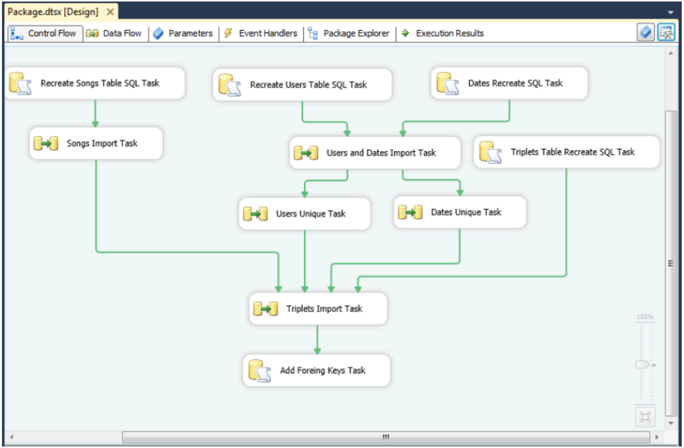

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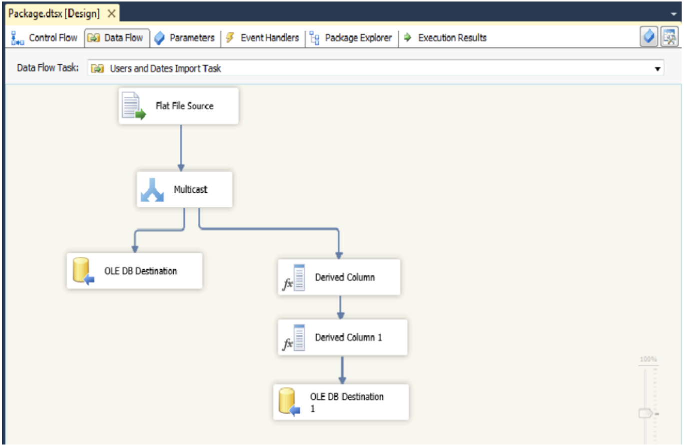

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  - Data sources can be designed using different logical structures.

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    1. the order has been received by a customer,
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  - It is a common problem that there is no table `SALES` in the operational databases; some other tables can exist like `ORDER` with an attribute `ORDER_STATUS`.

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- A load utility must allow the administrator to monitor status, to cancel, suspend, and resume a load, and to restart after failure with no loss of data integrity.

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- Update indexes, subaggregates and any other additional data structures.

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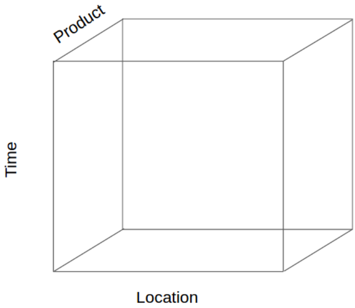
OLAP systems

- The next step is to provide solutions for querying and reporting multidimensional analytical data.

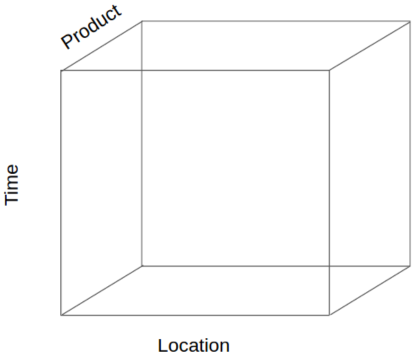
Multidimensional cube

- The proper data model for multidimensional reporting is the multidimensional one.



Operations in multidimensional data model

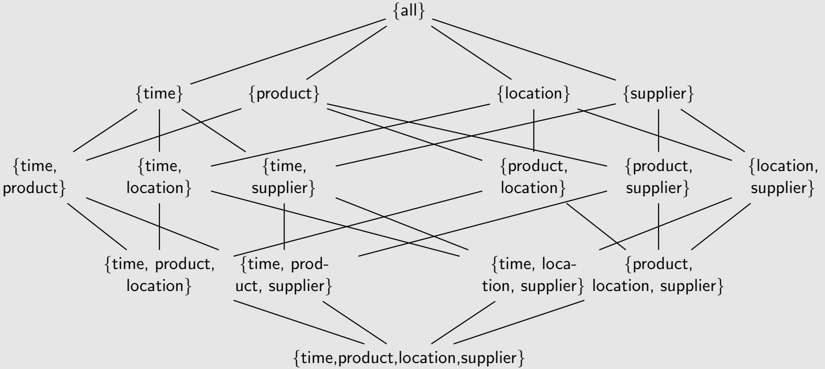
- Roll up – summarize data along a dimension hierarchy.
- Drill down – go from higher level summary to lower level summary or detailed data.
- Slice and dice – corresponds to selection and projection.
- Pivot – reorient cube.
- Raking, Time functions, etc.



Lattice of cuboids

- Different degrees of summarizations are presented as a lattice of cuboids.

Example for dimensions: time, product, location, supplier



Using this structure, one can easily show roll up and drill down operations.

Total number of cuboids

- For an n-dimensional data cube, the total number of cuboids that can be generated is:

$$T = \prod_{i=1}^{n} (L_i + 1)\,,$$

where L_i is the number of levels associated with dimension i (excluding the virtual top level "all" since generalizing to "all" is equivalent to the removal of a dimension).

- For example, if the cube has 10 dimensions and each dimension has 4 levels, the total number of cuboids that can be generated will be:

$$T = 5^{10} = 9,8 \times 10^6\,.$$

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Total number of cuboids

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  - Columns in `Date` dimension: `day`, `month`, `year`
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$\emptyset$		$\emptyset$
day		street
month		city
year		country
day, month	$\bowtie$	street, city
day, year		street, country
month, year		city, country
day, month, year		street, city, country

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Three types of aggregate functions

- distributive: `count()`, `sum()`, `max()`, `min()`,
- algebraic: `ave()`, `stddev()`,
- holistic: `median()`, `mode()`, `rank()`.

OLAP servers

- Relational OLAP (ROLAP),
- Multidimensional OLAP (MOLAP),
- Hybrid OLAP (HOLAP).

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    - A huge number of cells is empty: a customer is not able to buy all products in all locations ...

HOLAP

- HOLAP servers are a hybrid approach that combines ROLAP and MOLAP technology.
- HOLAP benefits from the greater scalability of ROLAP and the faster computation of MOLAP.

Outline

Multidimensional queries

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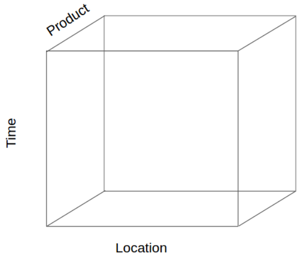
  - Operations like roll up, drill down, slice and dice, pivoting, ranking, time and window functions, etc.



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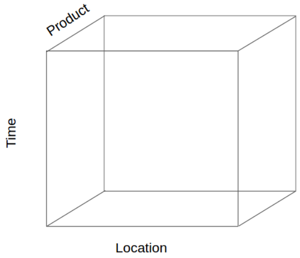

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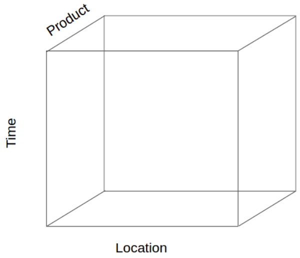

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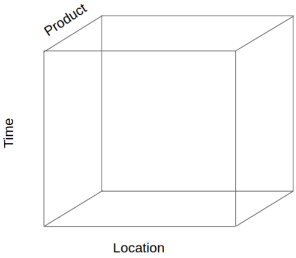

- Two solutions:
  - Extending **SQL**, or
  - Inventing a new language ($\rightarrow$ **MDX**).

OLAP queries in SQL

- A typical example of an analytical query is a group-by query:

```
SELECT Instructor, Academic_year, AVG(Grade)
FROM Data_Warehouse
GROUP BY Instructor, Academic_year
```

- And the result:

Academic_year	Name	AVG(Grade)
2013/14	Stefanowski	4.2
2014/15	Stefanowski	4.5
2013/14	Słowiński	4.1
2014/15	Słowiński	4.3
2014/15	Dembczyński	4.6

SQL

- OLAP extensions in SQL:
  - **GROUP BY CUBE**,
  - `GROUP BY ROLLUP`,
  - `GROUP BY GROUPING SETS`,
  - **OVER** and **PARTITION BY**,
  - `RANK`.

SQL

- `GROUP BY CUBE`

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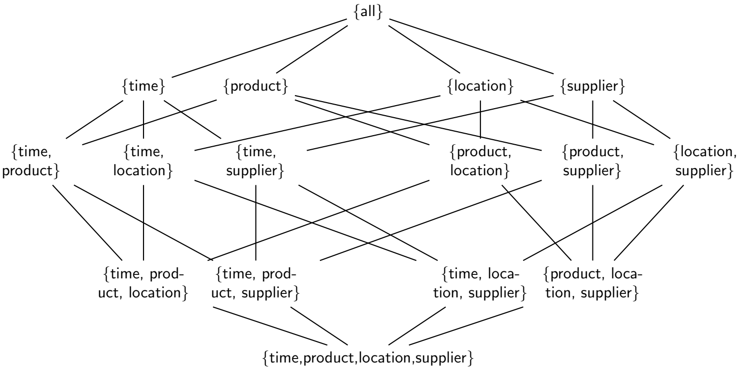
  - **Example**:

```
SELECT Time, Product, Location, Supplier, SUM(Gain)
FROM Sales
GROUP BY CUBE (Time, Product, Location, Supplier);
```



SQL

- GROUP BY CUBE
  - **Example**:

```
SELECT Time, Product, Location, Supplier, SUM(Gain)
FROM Sales
GROUP BY Time, Product, Location, Supplier
UNION ALL
SELECT Time, Product, Location, ''*'', SUM(Gain)
FROM Sales
GROUP BY Time, Product, Location
UNION ALL
SELECT Time, Product, ''*'', Location, SUM(Gain)
FROM Sales
GROUP BY Time, Product, Location
UNION ALL
...
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SELECT '*', '*', '*', '*', SUM(Gain)
FROM Sales;
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- `GROUP BY CUBE`
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  - It is not only a *Macro* instruction to reduce the number of subgroup-bys.
  - One can easily optimize the group-by operations, when they are performed all-together: upper-level group-bys can be computed from lower-level group-bys.

SQL

- GROUP BY CUBE
  - **Example**:
    SELECT Academic year, Name, AVG(Grade) FROM Students_grades GROUP BY CUBE(Academic year, Name);

All rows and columns

Academic_year	Name	AVG(Grade)
2011/2	Stefanowski	4.2
2011/2	Słowiński	4.1
2012/3	Stefanowski	4.0
2012/3	Słowiński	3.8
2013/4	Stefanowski	3.9
2013/4	Słowiński	3.6
2013/4	Dembczyński	4.8

Academic_year	AVG(Grade)
2011/2	4.15
2012/3	3.85
2013/4	3.8

Name	AVG(Grade)
Stefanowski	3.9
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  - Syntax:

```
OVER (
    [ <PARTITION BY clause> ]
    [ <ORDER BY clause> ]
    [ <ROW or RANGE clause> ]
)
```

SQL

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    - The `RANGE` clause logically limits the rows within a partition by specifying a range of values with respect to the value in the current row.
    - Preceding and following rows are defined based on the ordering in the `ORDER BY` clause.

SQL

- **Example**

SQL

- **Example**
  - Student grades with the average:

```
SELECT Student, Instructor, Lecture, Academic_year,
grade, AVG (grade) OVER (PARTITION BY Student)
FROM Grades;
```

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$\downarrow$

AVG(Grade)	Academic_year		
Name	2011/2	2012/3	2013/4
Stefanowski	4.2	4.0	3.9
Słowiński	4.1	3.8	3.6
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MDX

- MDX query:

```
SELECT {[Academic Year].[2011/2],[Academic
Year].[2012/13],[Academic Year].[2013/14]} ON COLUMNS,
{[Instructor].[Stefanowski],[Instructor].[Slowinski],
[Instructor].[Dembczynski]} ON ROW
FROM PUT
WHERE ([Measures].[Average Grades])
```

- Seems to be similar to **SQL**, but in fact it is quite **different**!

Outline

Summary

- ETL process is a strategic element of data warehousing.
- Main concepts: extraction, transformation and integration, load, data warehouse refreshment and metadata.
- New emerging technology ...
- OLAP systems: ROLAP, MOLAP and HOLAP.
- Two main approaches for querying data warehouses.
  - ROLAP servers: SQL and its OLAP extensions.
  - MOLAP servers: MDX.

Bibliography

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- Mark Whitehorn, Robert Zare, and Mosha Pasumansky. *Fast Track to MDX*. Springer, 2002