Evolution of Database Systems

Krzysztof Dembczyński

Intelligent Decision Support Systems Laboratory (IDSS)
Poznań University of Technology, Poland

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Review of the Previous Lecture

- Mining of massive datasets.
- Classification and regression.

Outline

1. Evolution of database systems
2. Analytical database systems
3. Processing of massive datasets
4. Summary

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2. Analytical database systems
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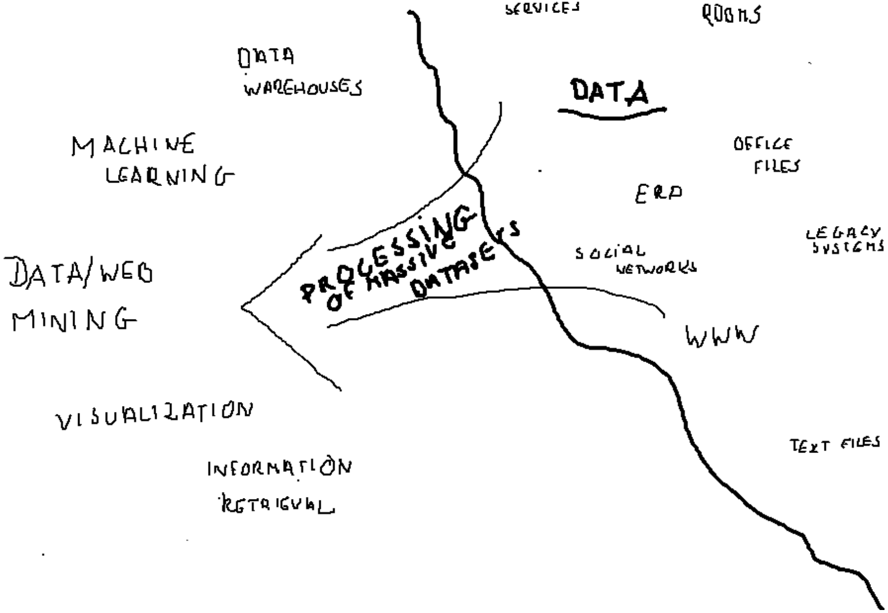
SERVICES
DATA WAREHOUSES
DATA
MACHINE LEARNING
OFFICE FILES
ERP
LEGACY SYSTEMS
PROCESSING OF MASSIVE DATASETS
SOCIAL NETWORKS
DATA/WEB MINING
WWW
VISUALIZATION
TEXT FILES
INFORMATION RETRIEVAL

Data is the new oil (?)

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  - Control access to data from many users at once in isolation and ensure the actions on data to be performed completely.

Data models

- **Data model** is an abstract model that defines how data is represented and accessed.
  - **Logical data model** – from a user's point of view
  - **Physical data model** – from a computer's point of view.
- Data model defines:
  - Data objects and types, relationships between data objects, and constraints imposed on them.
  - Operations for defining, searching and updating data.

Approaches to data management

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- NoSQL and BigData
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- *NewSQL*
- **The choice of the approach strongly depends on a given application!**

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  - No declarative query language (requires more programming, but new paradigms like MapReduce appear)

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  - graph database systems.
- Design for different purposes.

BigData – a lot of Vs[1]

- **Volume**: the quantity of generated and stored data.
- **Variety**: the type and nature of the data.
- **Velocity**: the speed at which the data is generated and processed.
- **Variability**: inconsistency of the data.
- **Value**: the value of the data.

[1] https://en.wikipedia.org/wiki/Big_data

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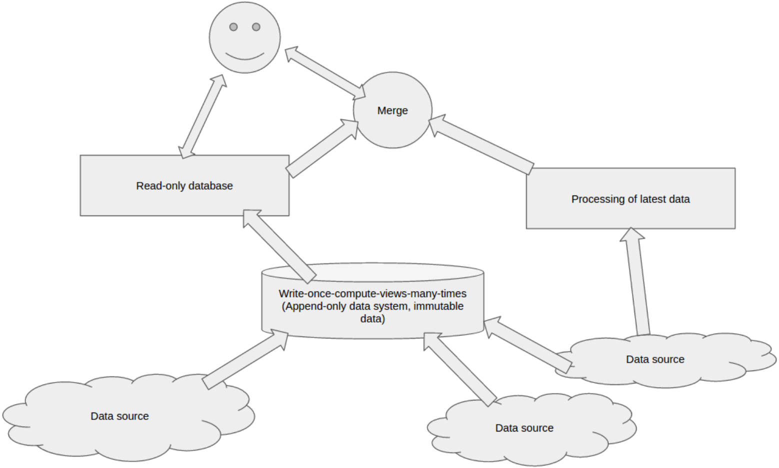
  - Database systems of a **write-once-read-many-times** type.

Outline

Analytical database systems

- Data warehouses,
- Business intelligence,
- Computational and analytical tools,
- Scientific databases,
- Analytics engines for large-scale data processing.

Analytical database systems



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    - **Non-volatile**: warehouse data is loaded and accessed; update of data does not occur in the data warehouse environment.
    - **Time-variant**: the time horizon for the data warehouse is significantly longer than that of operational systems.

Life-cycle of analytical database systems

- Logical design of the database
- Design and implementation of ETL (extraction, transformation, load) process
- Deployment of the system
- Optimization of the system
- Refreshing of the data

Logical design of the database

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Logical design of the database

- University authorities decided to analyze teaching performance by using the data collected in databases owned by the university containing information about students, instructors, lectures, faculties, etc.
- They would like to get answers for the following queries:
  - What is the average score of students over academic years?
  - What is the number of students over academic years?
  - What is the average score by faculties, instructors, etc.?
  - What is the distribution of students over faculties, semesters, etc.?
  - ...

Example

- An exemplary query could be the following:

```
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

Motivation

- The result is also commonly given as a pivot table:

AVG(Grade)	Academic_year	
Name	2013/2014	2014/2015
Stefanowski	4.2	4.5
Słowiński	4.1	4.3
Dembczyński		4.6

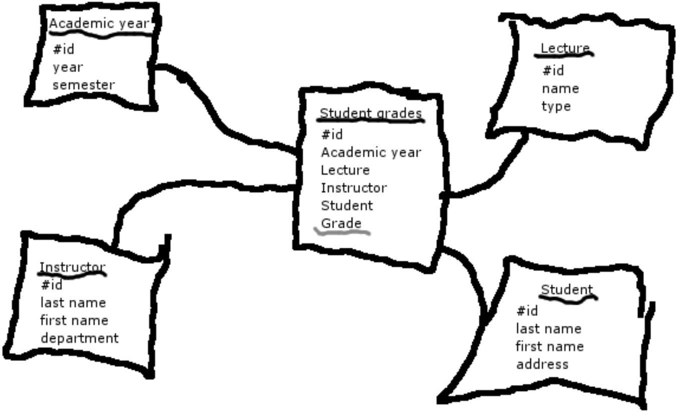
- Three main goals for logical design:
  - Simplicity:
    - Users should understand the design,
    - Data model should match users' conceptual model,
    - Queries should be easy and intuitive to write.
  - Expressiveness:
    - Include enough information to answer all important queries,
    - Include all relevant data (without irrelevant data).
  - Performance:
    - An efficient physical design should be possible to apply.

Three basic conceptual schemes

- Star schema,
- Snowflake schema,
- Fact constellations.

Star schema

- A single table in the middle connected to a number of dimension tables.



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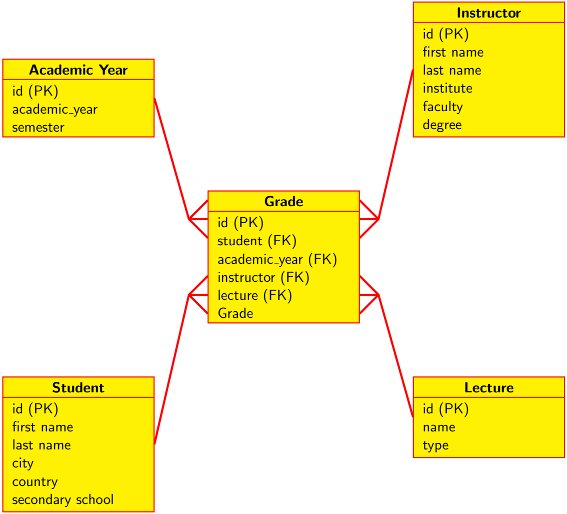

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- **Dimension tables**
  - Represent information about dimensions (student, academic year, etc.).
  - Each dimension has a set of descriptive attributes.

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- The aggregated fact columns are the matter of the analysis.

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- Dimension tables describe facts stored in the fact table.

Fact table vs. Dimension tables

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Facts contain numbers, dimensions contain labels

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- **Normalize until it hurts, denormalize until it works** :)

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  - Choose the dimensions describing the business process (e.g. localization, product, data, promotion, etc.).
  - Identify the numeric measures for the facts (e.g. price, quantity).
- Date and time dimension,
- Surrogate keys,
- Degenerate dimension,
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Important aspects of dimensional modeling

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- Factless fact tables.

Multidimensional data model

- Retail sales data:

Location:Vancouver				
Time (quarters)	Items			
	TV	Computer	Phone	Security
Q1	605	825	14	400
Q2	680	952	31	512
Q3	812	1023	30	501
Q4	927	1038	38	580

Multidimensional data model

- Similar information for other cities:

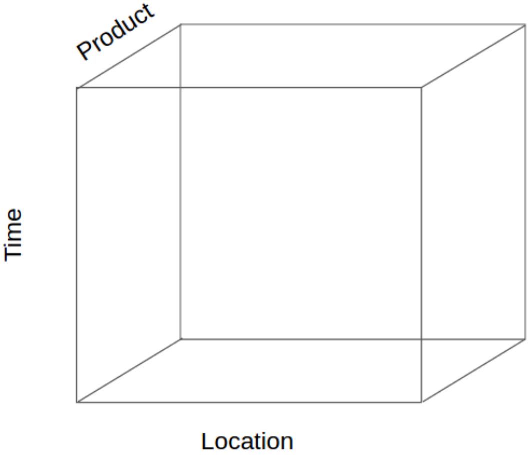
Location:Vancouver				
Time	Items			
(quarters)	TV	Computer	Phone	Security
Q1	605	825	14	400
Q2	680	952	31	512
Q3	812	1023	30	501
Q4	927	1038	38	580

Location:Toronto				
Time	Items			
(quarters)	TV	Computer	Phone	Security
Q1	1087	968	38	872
Q2	1130	1024	41	952
Q3	1034	1048	45	1002
Q4	1142	1091	52	984

Location:Chicago				
Time	Items			
(quarters)	TV	Computer	Phone	Security
Q1	854	882	89	623
Q2	943	890	64	698
Q3	1023	924	59	789
Q4	1129	992	63	870

Location:New York				
Time	Items			
(quarters)	TV	Computer	Phone	Security
Q1	818	746	43	591
Q2	894	769	52	682
Q3	940	795	58	728
Q4	978	864	59	784

Multidimensional cube



- More dimensions possible.

Different levels of aggregation

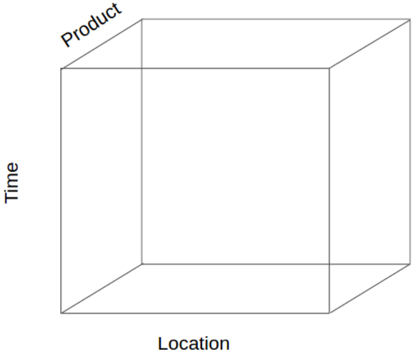
- Sales(time, product, *)

Time (quarters)	Items			
	TV	Computer	Phone	Security
Q1	3364	3421	184	2486
Q2	3647	3635	188	2817
Q3	3809	3790	186	3020
Q4	4176	3985	212	3218

- Sales(time, *, *); Sales(*, *, *)

Operators 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.



Exploring the cube

Time (quarters)	Items			
	TV	Computer	Phone	Security
Q1	3364	3421	184	2486
Q2	3647	3635	188	2817
Q3	3809	3790	186	3020
Q4	4176	3985	212	3218

$\Leftrightarrow$

Time		Items			
		TV	Computer	Phone	Security
Q1		3364	3421	184	2486
Q2		3647	3635	188	2817
Q3		3809	3790	186	3020
Q4	October	1172	960	105	1045
	November	1005	1340	45	987
	December	1999	1685	62	1186

Outline

Processing of massive datasets

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- Data schemas: star schema, flexible schemas.

Outline

Summary

- Significant difference between operational and analytical systems.
- Different data models dedicated to particular applications.
- NoSQL = "Not only traditional relational DBMS."
- OLAP vs. OLTP.
- Star schema.
- Multidimensional data model.
- Processing of massive datasets.

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