Evolution of Database Systems

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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
Outline

1. Evolution of database systems
2. Analytical database systems
3. Processing of massive datasets
4. Summary
Data is the new oil (?)
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Database management system

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  - Enable durability, the recovery of the database in the face of failures,
  - 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

- File management system
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- File management system
- Database management system
  - Early database management systems (e.g. hierarchical or network data models)

- NoSQL and BigData
- NewSQL

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

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- **No** means rather “Not only” and **SQL** states for “traditional relational DBMS”.

  - Flexible schema (less restricted than typical RDBMS, but may not support join operations)
  - Quicker/cheaper to set up
  - Massive scalability (scale-out instead of scale-up)
  - Relaxed consistency → higher performance and availability, but fewer guarantees (like ACID)
  - Not all operations supported (e.g., join operation)
  - No declarative query language (requires more programming, but new paradigms like MapReduce appear)
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• Design for different purposes.
BigData – a lot of Vs¹

- **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](https://en.wikipedia.org/wiki/Big_data)
Two types of systems

- Operational systems:
  - Support day-to-day operations of an organization.
  - Also referred to as on-line transaction processing (OLTP).
  - Main tasks: processing of a huge number of concurrent transactions, and insuring data integrity.

- Analytical systems:
  - Support knowledge workers (e.g., manager, executive, analyst) in decision making.
  - Also referred to as on-line analytical processing (OLAP).
  - Main tasks: effective processing of multidimensional queries concerning huge volumes of data.
  - Database systems of a write-once-read-many-times type.
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Analytical database systems

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

- Read-only database
- Processing of latest data
- Write-once-compute-views-many-times (Append-only data system, immutable data)

Data sources:
- Data source
- Data source
- Data source
Analytical database systems

• The old and still good definition of the data warehouse:

  - **Subject oriented**: oriented to the major subject areas of the corporation that have been defined in the data model.
  - **Integrated**: there is no consistency in encoding, naming conventions, etc., among different data sources that are heterogeneous data sources (when data is moved to the warehouse, it is converted).
  - **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.
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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
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.?
- . . .
Logical design of the database

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  ▶ ...
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:

<table>
<thead>
<tr>
<th>Academic_year</th>
<th>Name</th>
<th>AVG(Grade)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013/14</td>
<td>Stefanowski</td>
<td>4.2</td>
</tr>
<tr>
<td>2014/15</td>
<td>Stefanowski</td>
<td>4.5</td>
</tr>
<tr>
<td>2013/14</td>
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<td>4.1</td>
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<td>4.3</td>
</tr>
<tr>
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• The result is also commonly given as a pivot table:

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Conceptual schemes of data warehouses

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

- Each fact table contains measurements about a process of interest.
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- Any new fact is added to the fact table.
- The aggregated fact columns are the matter of the analysis.
Dimension tables

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- Dimension tables describe facts stored in the fact table.
Fact table vs. Dimension tables

- Fact table:

Facts contain numbers, dimensions contain labels
Fact table vs. Dimension tables

- Fact table:
  - narrow,
  - big (many rows),
  - numeric (rows are described by numerical measures),
  - dynamic (growing over time).

- Dimension table
  - wide,
  - small (few rows),
  - descriptive (rows are described by descriptive attributes),
  - static.

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Denormalization

- Denormalization is the process of attempting to optimize the performance of a database by adding redundant data or by grouping data.
- Denormalization helps cover up the inefficiencies inherent in relational database software.
- **Normalize until it hurts, denormalize until it works :)**
Important aspects of dimensional modeling

• Four step procedure:
Important aspects of dimensional modeling

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• Slowly changing dimensions,
• Mini dimension,
• Factless fact tables.
Multidimensional data model

- Retail sales data:

<table>
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<tr>
<th>Location: Vancouver</th>
<th>Time (quarters)</th>
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Multidimensional data model

- Similar information for other cities:

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<tr>
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- More dimensions possible.
Different levels of aggregation

- Sales(time, product, *)

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- 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

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Outline

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

• Physical data organization: row-based, column-based, key-values stores, multi-dimensional arrays, etc.
• Partitioning and sharding (Map-Reduce, distributed databases).
• Data access: hashing and sorting (tree-based indexing).
• Advanced data structures: multi-dimensional indexes, inverted lists, bitmaps, special-purpose indexes.
• Summarization, materialization, and denormalization.
• Data compression.
• Approximate query processing.
• Probabilistic data structures and algorithms.
• Data schemas: star schema, flexible schemas.
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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.
