Acknowledgements: I am indebted to Michael Böhlen and Stefano Rizzi for providing me their slides, upon which these lecture notes are based.
Outline

1. Course Organization
2. The DB Field
3. The Need for Advanced Data Management Technologies
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Course Organization

Course page
- http://www.inf.unibz.it/dis/teaching/ADMT or https://ole.unibz.it
- Here you can find the schedule, lecture notes, office hours, etc.

Organization
- The course consists of lectures and a project
- Lectures are organized as frontal teaching classes
- The lab is organized as a project
- Lab hours are used to discuss with you the progress in the project
- We also plan an excursion to a company
Course Content

- The course introduces **advanced data management technologies**:
  - Data Warehousing and Business Intelligence
  - OLAP
  - Extract, Transform, Load
  - NoSQL
  - Main-memory Databases
  - Column-oriented Databases
  - Distributed Databases
  - Distributed Data Structures

- The course is **research-oriented**
  - Many concepts we discuss are not available in commercial (DBMS) systems
  - There is no single course book; much of the material is based on research papers
The assessment of the course consists of two parts:

- **theory (60%)**: assessed with a written exam at the end;
- **project (40%)**: assessed through a presentation, demo and final report about the project.

Both parts must be positive to pass the exam.

A positive project is required for attending the theory part.

The final grade is the weighted average between the two parts.
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Literature and Resources

- **Journal Publications**
  - ACM Transaction on Database System (TODS)
  - IEEE Transactions on Knowledge and Data Engineering (TKDE)
  - The VLDB Journal
  - Information Systems

- **Conference Publications**
  - ACM SIGMOD International Conference on Management of Data (SIGMOD)
  - International Conference on Very Large Databases (VLDB)
  - International Conference on Extending Database Technology (EDBT)
  - IEEE International Conference on Data Engineering (ICDE)

- **DB & LP Bibliography (maintained by Michael Ley, Uni Trier, Germany)**
  - http://www.informatik.uni-trier.de/~ley/db/
(Commercial) Products

- Oracle
- DB2 (IBM)
- Microsoft SQL Server
- Teradata
- Sybase
- Ingres
- Informix
- PostgreSQL
- PC “DBMSs”: Paradox, Access, …
- …
DB Research and Practice has Many Aspects

- Design of languages
- Development of algorithms
- Data modeling
- User interface design
- Design of migration strategies
- Distributed computing
- High data volumes and efficiency
- New data models and systems
  - XML/semi-structured databases
  - Temporal, spatial, moving object databases
  - Stream data processing
- ...

The Relational Data Model/1

- Data are stored in relations/tables

<table>
<thead>
<tr>
<th>employee</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Name</td>
<td>Dept</td>
<td>Salary</td>
</tr>
<tr>
<td>Tom</td>
<td>SE</td>
<td>23K</td>
</tr>
<tr>
<td>Lena</td>
<td>DB</td>
<td>33K</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>department</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Dname</td>
<td>Manager</td>
<td>Address</td>
</tr>
<tr>
<td>SE</td>
<td>Tom</td>
<td>Boston</td>
</tr>
<tr>
<td>DB</td>
<td>Lena</td>
<td>Tucson</td>
</tr>
</tbody>
</table>

| project     |               |           |           |
|-------------|---------------|-----------|
| PId | Dept | From           | To           |
| 14  | SE   | 01.01.2005       | 31.12.2005    |
| 201 | DB   | 15.04.2005       | 31.03.2006    |

- SQL as query (and data definition) language
  - Intergalactic dataspeak [Stonebreaker]
A domain $D$ is a set of atomic data values.
- phone numbers, names, grades, birthdates, departments
- each domain includes the special value \texttt{null} for unknown or missing value
With each domain a data type or format is specified.
- 5 digit integers, yyyy-mm-dd, characters
An attribute $A_i$ describes the role of a domain in a relation schema.
- PhoneNr, Age, DeptName
A relation schema $R(A_1, ..., A_n)$ is made up of a relation name $R$ and a list of attributes.
- \texttt{employee(Name, Dept, Salary)}, \texttt{department(DName, Manager, Address)}
A tuple $t$ is an ordered list of values $t = (v_1, ..., v_n)$ with $v_i \in \text{dom}(A_i)$.
- $t = (\text{Tom}, \text{SE}, 23K)$
A relation $r$ of the relation schema $R(A_1, ..., A_n)$ is a set of n-ary tuples.
- $r = \{(\text{Tom}, \text{SE}, 23K), (\text{Lene}, \text{DB}, 33K)\}$
A database $DB$ is a set of relations.
- $DB = \{r, s\}$
- $r = \{(\text{Tom}, \text{SE}, 23K), (\text{Lene}, \text{DB}, 33K)\}$
- $s = \{(\text{SE}, \text{Tom}, \text{Boston}), (\text{DB}, \text{Lena}, \text{Tucson})\}$
Properties of Relations

- A relation is a set of tuples, i.e.,
  - no ordering between tuples and
  - no duplicates (identical tuples) exist.
- Attributes within tuples are ordered.
  - At the logical level it is possible to have unordered tuples if the correspondence between values and attributes is maintained
  - e.g., \{\text{Salary}/23K, \text{Name}/Tom, \text{Dept}/SE\}
The success of DBs also depends on the ease of data access.

Various interfaces to DBs exist, e.g.,

- Terminal interface (sqlplus, etc.)
- OCI (Oracle Call Interface)
- X/Open SQL CLI (Call Level Interface)
- ODBC (Open Data Base Connection), iODBC for Unix
- JDBC (Java Database Connectivity)
- DBI (Perl DB Interface)
- Embedded SQL
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In the light of new trends, the relational model is not sufficient anymore!

At least three interrelated megatrends in the last few years

- Big Data
- Big Users
- Cloud Computing
New Trends/2

- **Big Data**
  - Database volumes have grown continuously since the earliest days of computing, but that growth has intensified dramatically over the past decade.
  - e.g., social networks, Facebook, Google, geo location data, sensor-generated data, scientific data, Internet of Things, Industry 4.0, etc.
  - Huge data repositories, e.g., in astronomy, finance, Web, ... 

- **Big Users**
  - Not long ago, 1,000 daily users was a lot and 10,000 was an extreme case.
  - Today, millions of users a day is not uncommon, and users have very different needs.
  - As a consequence, developers need more flexibility to store/access the data.

- **Cloud Computing**
  - Has placed new challenges on the database.
  - Provide computing resources on demand with a "pay-as-you-go" model.
  - Traditional RDBMSs were unable to provide these types of elastic services.
The Need for Advanced Data Management Technologies

With the increase in data and users, applications have changed dramatically over the last 15 years, and so have the data management needs of those apps.

Relational databases are schema-based, hence rather rigid; new more flexible and scalable data models are needed.

ACID properties are not always needed; scalability is more important!

Data is distributed, thus database solutions are needed that are distributed on large numbers of hosts across a network.

We study new data management technologies in the second part of the course.
On the other hand, the immense value of data has been recognized by businesses.

Thus, analysis and mining of data has become an important tool in decision making for most businesses.

An exponential increase in operational data has made computers the only tools suitable for providing data for decision-making performed by business managers.

The massive use of techniques for analyzing enterprise data made information systems a key factor to achieve business goals.

⇒ We study Business Intelligence and Data Warehousing in the first part of the course.
Summary

- New trends in the last few years: **big data, big users, cloud computing**
- With the increase in data and users
  - **new data management technologies are needed:** more flexible, scalable, relaxed ACID
  - businesses recognized the **immense value of data** for decision making