Overview of Data Management

Grant Weddell

David R. Cheriton School of Computer Science
University of Waterloo

CS 348
Introduction to Database Management
Spring 2012

Course Logistics

Webpage	• www.cs.uwaterloo.ca/∼gweddell/cs348
Text Book	• *Database Management Systems (3rd Edition).* Raghu Ramakrishnan and Johannes Gehrke. McGraw Hill, 2000.

Course Content

Why do we use databases?

- Functionality provided by a Database Management System
- Database Models: Relational, Network, OO

How do we use a DBMS?

- Relational model, foundational query languages
- SQL
- Application programming
- Transactions and concurrency

How do we design a database?

- Entity-Relationship (ER) modeling
- Dependencies and constraints
- Redundancy and normal forms

How do we administer a DBMS?

- Security and authorization
- Physical design/tuning

What is a Database?

Definition (Database)

A *large* and *persistent* collection of (more-or-less similar) pieces of information organized in a way that facilitates efficient *retrieval* and *modification*.

Examples:

- a file cabinet
- a library system
- a personnel management system

Definition (Database Management System (DBMS))

A program (or set of programs) that manages details related to storage and access for a database.

Application of Databases

Original
- inventory control
- payroll
- banking and financial systems
- reservation systems

More recent
- computer aided design (CAD)
- software development (CASE, SDE/SSE)
- telecommunication systems
- e-commerce
- dynamic/personalized web content

Application of Databases (cont'd)

Common Circumstances:

- There is lots of data (mass storage)
- Data is formatted
- Requirements:
  - persistence and reliability
  - efficient and concurrent access
- Issues:
  - many files with different structure
  - shared files or replicated data
  - need to exchange data (translation programs)

Note

The data maintained by the system are much more important and valuable then the system itself.

Brief History of Data Management: Ancient

2000 BC: Sumerian Records

350 BC: Syllogisms (Aristotle)

296 BC: Library of Alexandria

1879: Modern Logic (Frege)

1884: U.S. Census (Hollerith)

1941: Model Theory (Tarski)

Brief History of Data Management: 1950s

First generation 50's and 60's

- batch processing
- sequential files and tape
- input on punched cards

Second generation (60's)

- disk enabled random access files
- new access methods (ISAM, hash files)
- mostly batch with some interactivity
- independent applications with separate files
- growing applications base

Brief History of Data Management: 1960s (cont'd)

As the application base grows, we end up with

- many shared files
- a multitude of file structures
- a need to exchange data among applications

This causes a variety of problems

- redundancy: multiple copies
- inconsistency: independent updates
- inaccuracy: concurrent updates
- incompatibility: multiple formats
- insecurity: proliferation
- inauditability: poor chain of responsibility
- inflexibility: changes are difficult to apply

Brief History of Data Management: 1960s (cont'd)

- Hierarchical data model
  - IBM's Information Management System (IMS): concurrent access
  - only allows 1:N parent-child relationships (i.e. a tree)
  - hierarchy can be exploited for efficiency
  - queries navigate up and down trees—one record at a time
  - data access language embedded in business processing language
  - difficult to express some queries
- Network data model
  - Charles Bachman's Integrated Data Store (IDS)
  - model standardized by Conference On DAta SYstems Languages (CODASYL)
  - data organized as collections of sets of records
  - separation of physical data representation from users' view of data
  - pointers between records represent relationships
  - set types encoded as lists
  - queries navigate between records—still one record at a time

Database Management System

Idea

Abstracts common functions and creates a uniform well defined interface for applications accessing data.

1. Data Model
   all data stored in a well defined way
2. Access control
   only authorized people get to see/modify it
3. Concurrency control
   multiple concurrent applications access data
4. Database recovery
   nothing gets accidentally lost
5. Database maintenance

Brief History of Data Management: 1970s

- Edgar Codd proposes relational data model (1970)
  - firm mathematical foundation $\rightarrow$ *declarative* queries
- *Charles Bachman wins ACM Turing award (1973)*
  - "The Programmer as Navigator"
- Peter Chen proposes E-R model (1976)
- Transaction concepts (Jim Gray and others)
- IBM's System R and UC Berkeley's Ingres systems demonstrate feasibility of relational DBMS (late 1970s)

Three Level Schema Architecture

Definition (Schema)

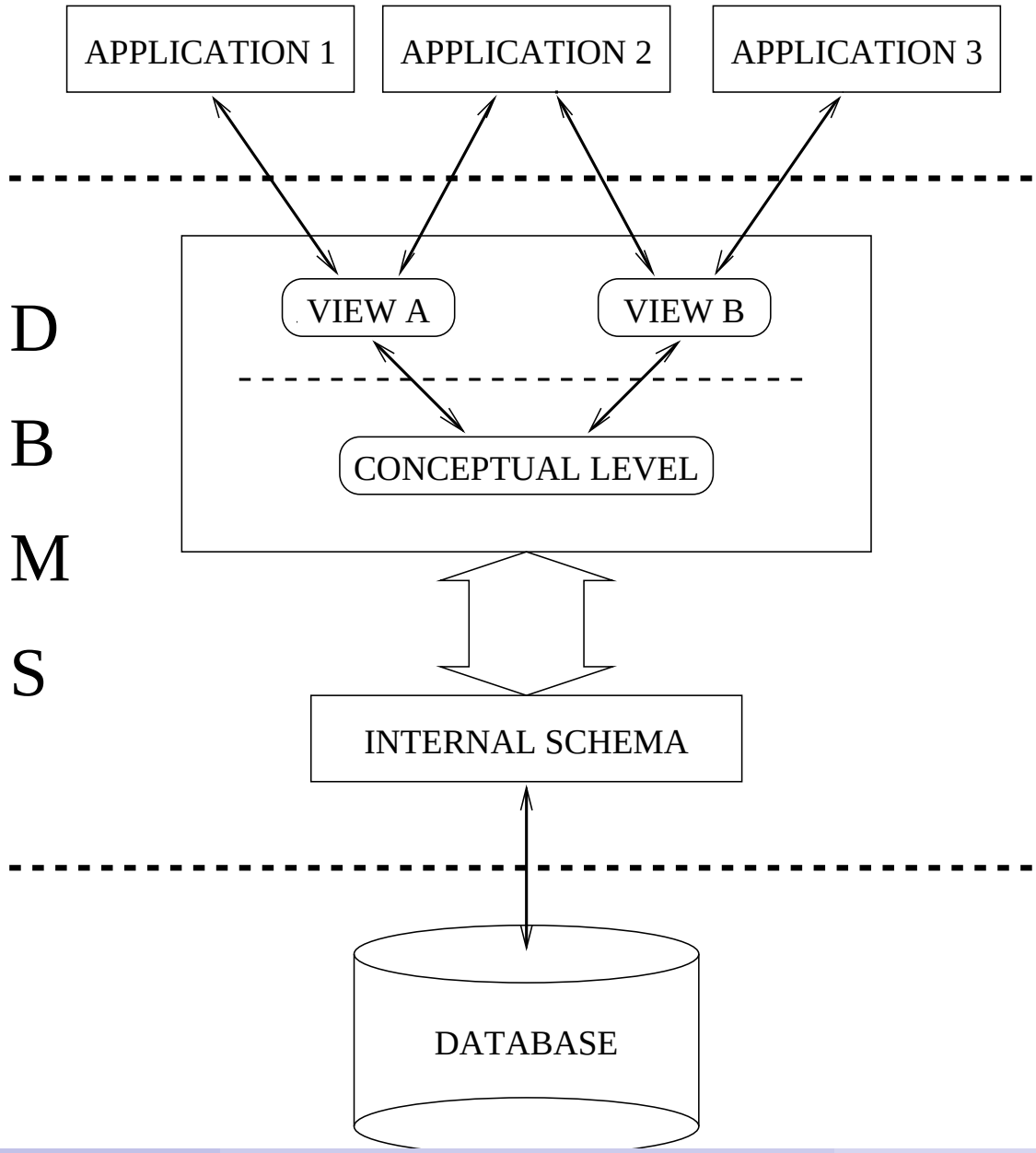
A **schema** is a description of the data interface to the database (i.e., how the data is organized).

1. External schema (view): what the application programs and user see. May differ for different users of the same database.
2. Conceptual schema: description of the logical structure of *all* data in the database.
3. Physical schema: description of physical aspects (selection of files, devices, storage algorithms, etc.)

Definition (Instance)

A **database instance** is a database (real data) that conforms to a given schema.

Three-level Schema Architecture (cont.)



Data Independence

Idea

Applications do not access data directly but, rather through an abstract data model *provided by the DBMS.*

Two kinds of data independence:

- Physical: applications immune to changes in storage structures
- Logical: applications immune to changes in data organization

Note

One of the most important reasons to use a DBMS!

Interfacing to the DBMS

Data Definition Language (DDL): for specifying schemas

- may have different DDLs for external schema, conceptual schema, internal schema
- information is stored in the **data dictionary**, or **catalog**

Data Manipulation Language (DML): for specifying queries and updates

- **navigational** (procedural)
- **non-navigational** (declarative)

Types of Database Users

End user:

- Accesses the database indirectly through forms or other query-generating applications, or
- Generates ad-hoc queries using the DML.

Application developer:

- Designs and implements applications that access the database.

Database administrator (DBA):

- Manages conceptual schema.
- Assists with application view integration.
- Monitors and tunes DBMS performance.
- Defines internal schema.
- Loads and reformats database.
- Is responsible for security and reliability.

Transactions

When multiple applications access the same data, undesirable results occur.

Example:

```
withdraw(AC,1000)
  Bal := getbal(AC)

  if (Bal>1000)
    <give-money>
    setbal(AC,Bal-1000)
```

```
withdraw(AC,500)

  Bal := getbal(AC)
  if (Bal>500)
    <give-money>

    setbal(AC,Bal-500)
```

Idea

Every application may think it is the sole application accessing the data. The DBMS should guarantee correct execution.

Transactions (cont'd)

Definition (Transaction)

An application-specified atomic and durable unit of work.

Properties of transactions ensured by the DBMS:

Atomic:	a transaction occurs entirely, or not at all
Consistency:	each transaction preserves the consistency of the database
Isolated:	concurrent transactions do not interfere with each other
Durable:	once completed, a transaction's changes are permanent

Brief History of Data Management: 1980s

- Development of commercial relational technology
  - IBM DB2, Oracle, Informix, Sybase
- *Edgar Codd wins ACM Turing award (1981)*
- SQL standardization efforts through ANSI and ISO
- Object-oriented DBMSs
  - persistent objects
  - object id's, methods, inheritence
  - navigational interface reminicent of hierarchical model

Brief History of Data Management: 1990s-Present

- Continued expansion of SQL and system capabilities
- New application areas:
  - the Internet
  - On-Line Analytic Processing (OLAP)
  - data warehousing
  - embedded systems
  - multimedia
  - XML
  - data streams
- *Jim Gray wins ACM Turing award (1998)*
- Relational DBMSs incorporate objects (late 1990s)

Summary

Using a DBMS to manage data helps:

- to remove common code from applications
- to provide uniform access to data
- to guarantee data integrity
- to manage concurrent access
- to protect against system failure
- to set access policies for data