Chapter 2: Concepts and Architecture

CS-6360 Database Design

Dr. Chris Irwin Davis
email: cid021000@utdallas.edu
phone: (972) 883-3574
office: ECSS 4.705
Chapter 2 Outline

• Data Models, Schemas, and Instances
• Three-Schema Architecture and Data Independence
• Database Languages and Interfaces
• The Database System Environment
• Centralized and Client/Server Architectures for DBMSs
• Classification of Database Management Systems
Concepts and Architecture

• Basic client/server DBMS architecture
  • **Client module**
  • **Server module**
Data Models and Schemas

• Data abstraction
  • Suppression of details of data organization and storage
  • Highlighting of the essential features for an improved understanding of data
Data Models and Schemas

• Data model
  • Collection of concepts that describe the structure of a database
  • Provides means to achieve data abstraction
  • Basic operations
    • Specify retrievals and updates on the database
  • Dynamic aspect or behavior of a database application
    • Allows the database designer to specify a set of valid operations allowed on database objects
Categories of Data Models

• **High-level or conceptual data models**
  • Close to the way many users perceive data

• **Low-level or physical data models**
  • Describe the details of how data is stored on computer storage media

• **Representational data models**
  • Easily understood by end users
  • Also similar to how data organized in computer storage
Categories of Data Models

- **Entity**
  - Represents a real-world object or concept

- **Attribute**
  - Represents some property of interest
  - Further describes an entity

- **Relationship** among two or more entities
  - Represents an association among the entities
  - **Entity-Relationship model**
Categories of Data Models

• Relational data model
  • Used most frequently in traditional commercial DBMSs

• Object data model
  • New family of higher-level implementation data models
  • Closer to conceptual data models
Categories of Data Models

• Physical data models
  • Describe how data is stored as files in the computer

• Access path
  • Structure that makes the search for particular database records efficient

• Index
  • Example of an access path
  • Allows direct access to data using an index term or a keyword
Schemas, Instances, and Database State

- **Database schema**
  - Description of a database
- **Schema diagram**
  - Displays selected aspects of schema
- **Schema construct**
  - Each object in the schema
- **Database state** or **snapshot**
  - Data in database at a particular moment in time
Schemas, Instances, and Database State

Figure 2.1
Schema diagram for the database in Figure 1.2.

<table>
<thead>
<tr>
<th>STUDENT</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Name</td>
<td>Student_number</td>
<td>Class</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>COURSE</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Course_name</td>
<td>Course_number</td>
<td>Credit_hours</td>
<td>Department</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PREREQUISITE</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Course_number</td>
<td>Prerequisite_number</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SECTION</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Section_identifier</td>
<td>Course_number</td>
<td>Semester</td>
<td>Year</td>
<td>Instructor</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>GRADE REPORT</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Student_number</td>
<td>Section_identifier</td>
<td>Grade</td>
</tr>
</tbody>
</table>

---

6 Schema changes are usually needed as the requirements of the database applications change. Newer database systems include operations for allowing schema changes, although the schema change process is more involved than simple database updates.

7 It is customary in database parlance to use schemas as the plural for schema, even though schemata is the proper plural form. The word scheme is also sometimes used to refer to a schema.
Schemas, Instances, and Database State

Figure 2.1
Schema diagram for the database in Figure 1.2.

**STUDENT**

<table>
<thead>
<tr>
<th>Name</th>
<th>Student_number</th>
<th>Class</th>
<th>Major</th>
</tr>
</thead>
</table>

**COURSE**

<table>
<thead>
<tr>
<th>Course_name</th>
<th>Course_number</th>
<th>Credit_hours</th>
<th>Department</th>
</tr>
</thead>
</table>

**PREREQUISITE**

<table>
<thead>
<tr>
<th>Course_number</th>
<th>Prerequisite_number</th>
</tr>
</thead>
</table>

**SECTION**

<table>
<thead>
<tr>
<th>Section_identifier</th>
<th>Course_number</th>
<th>Semester</th>
<th>Year</th>
<th>Instructor</th>
</tr>
</thead>
</table>

**GRADE_REPORT**

<table>
<thead>
<tr>
<th>Student_number</th>
<th>Section_identifier</th>
<th>Grade</th>
</tr>
</thead>
</table>

---

6 Schema changes are usually needed as the requirements of the database applications change. Newer database systems include operations for allowing schema changes, although the schema change process is more involved than simple database updates.

7 It is customary in database parlance to use *schemas* as the plural for *schema*, even though *schemata* is the proper plural form. The word *scheme* is also sometimes used to refer to a schema.
Schemas, Instances, and Database State

Figure 2.1
Schema diagram for the database in Figure 1.2.

STUDENT
- Name
- Student_number
- Class
- Major

COURSE
- Course_name
- Course_number
- Credit_hours
- Department

PREREQUISITE
- Course_number
- Prerequisite_number

SECTION
- Section_identifier
- Course_number
- Semester
- Year
- Instructor

GRADE_REPORT
- Student_number
- Section_identifier
- Grade

---

6. Schema changes are usually needed as the requirements of the database applications change. Newer database systems include operations for allowing schema changes, although the schema change process is more involved than simple database updates.

7. It is customary in database parlance to use *schemas* as the plural for *schema*, even though *schemata* is the proper plural form. The word *scheme* is also sometimes used to refer to a schema.
Schemas, Instances, and Database State

• **Define** a new database
  • Specify database schema to the DBMS

• **Initial state**
  • Populated or loaded with the initial data

• **Valid state**
  • Satisfies the structure and constraints specified in the schema

• **Schema evolution**
  • Changes applied to schema as application requirements change
Three-Schema Architecture and Data Independence

• Internal level
  • Describes physical storage structure of the database

• Conceptual level
  • Describes structure of the whole database for a community of users

• External or view level
  • Describes part of the database that a particular user group is interested in
Three-Schema Architecture and Data Independence

Figure 2.2
The three-schema architecture.

External Level
- External/Conceptual Mapping

Conceptual Level
- Conceptual/Internal Mapping

Internal Level
- Stored Database

End Users
- External View
  - . . .

Conceptual Schema
- Conceptual View
Data Independence

• Capacity to change the schema at one level of a database system
  • Without having to change the schema at the next higher level

• Types:
  • Logical
  • Physical

• For example, changing to a different DBMS or disk drive without having to change the schema.
DBMS Languages

• Data definition language (DDL)
  • Defines both schemas
• Storage definition language (SDL)
  • Specifies the internal schema
• View definition language (VDL)
  • Specifies user views/mappings to conceptual schema
• Data manipulation language (DML)
  • Allows retrieval, insertion, deletion, modification
DBMS Languages (cont'd.)

• **High-level** or **nonprocedural** (Declarative) DML
  • Can be used on its own to specify complex database operations concisely
  • **Set-at-a-time** or **set-oriented**

• **Low-level** or **procedural** DML
  • Must be embedded in a general-purpose programming language
  • **Record-at-a-time**, like ISAM
DBMS Interfaces

• Menu-based interfaces for Web clients or browsing
• Forms-based interfaces
• Graphical user interfaces (Like SSMS)
• Natural language interfaces
• Speech input and output
• Interfaces for parametric users
• Interfaces for the DBA
Database System Utilities

• Loading
  • Load existing data files

• Backup
  • Creates a backup copy of the database

• Database storage reorganization
  • Reorganize a set of database files into different file organizations

• Performance monitoring
  • Monitors database usage and provides statistics to the DBA
The Database System Environment

- DBMS component modules
  - Buffer management
  - Stored data manager
  - DDL compiler
  - Interactive query interface
    - Query compiler
    - Query optimizer
  - Precompiler
The Database System Environment

- DBMS component modules
  - Runtime database processor
  - System catalog
  - Concurrency control system
  - Backup and recovery system (Backup: it’s not whether you’re paranoid, it’s whether you’re paranoid enough.)
Figure 2.3
Component modules of a DBMS and their interactions.
Centralized and Client/Server Architectures for DBMSs

• Centralized DBMSs Architecture
  • All DBMS functionality, application program execution, and user interface processing carried out on one machine
  • This was the mainframe model, with dumb terminals. It is still widely used.
Basic Client/Server Architectures

• **Servers** with specific functionalities
  • **File server**
    • Maintains the files of the client machines.
  • **Printer server**
    • Connected to various printers; all print requests by the clients are forwarded to this machine
• **Web servers** or **e-mail servers**
Basic Client/Server Architectures

• **Client machines**
  • Provide user with:
    • Appropriate interfaces to utilize these servers
    • Local processing power to run local applications

• **Server**
  • System containing both hardware and software
  • Provides services to the client machines
    • Such as file access, printing, archiving, or database access
Two-Tier Client/Server Architectures for DBMSs

• Server handles
  • Query and transaction functionality related to SQL processing

• Client handles
  • User interface programs and application programs
Two-Tier Client/Server Architectures for DBMSs

• Open Database Connectivity (ODBC)
  • Provides application programming interface (API)
  • Allows client-side programs to call the DBMS
    • Both client and server machines must have the necessary software installed

• Java Database Connectivity (JDBC)
  • Allows Java client programs to access one or more DBMSs through a standard interface
Three-Tier and n-Tier Architectures for Web Applications

• **Application server** or **Web server**
  • Adds intermediate layer between client and the database server
  • Runs application programs and stores business rules

• **N-tier**
  • Divide the layers between the user and the stored data further into finer components
Service Oriented Architecture

• Many different components of a system are services
• These may reside in the same machine or different machines.
• Database service, various business process services, calendar service, etc.
Three-Tier Architecture

**Figure 2.7**
Logical three-tier client/server architecture, with a couple of commonly used nomenclatures.
Classification of Database Management Systems

• Data model
  • Relational
  • Object
  • Hierarchical and network (legacy)
  • Native XML DBMS

• Number of users
  • Single-user
  • Multiuser
Classification of Database Management Systems

• Number of sites
  • Centralized
  • Distributed
    • Homogeneous
    • Heterogeneous

• Cost
  • Open source
  • Different types of licensing
Classification of Database Management Systems

- Types of access path options
- General or special-purpose
Summary

• Concepts used in database systems
• Main categories of data models
• Types of languages supported by DMBSs
• Interfaces provided by the DBMS
• DBMS classification criteria:
  • Data model, number of users, number of sties, access paths, cost