Introduction to Database Systems

- Databases
- Database Management Systems (DBMS)
- Levels of Abstraction
- Data Models
- Database Languages
- Types of Users
- DBMS Function and Structure

In other words, a somewhat random list of words and concepts that are necessary to move on…

Read Chapter 1, including the historical notes on pages 29 - 31.

Concept #1: Databases & Database Management Systems

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What is a Database?

- According to the book:
  - Collection of interrelated data
  - Set of programs to access the data
  - A DBMS contains information about a particular enterprise
  - DBMS provides an environment that is both *convenient* and *efficient* to use.

- Another definition (know these):
  - A *database* is a collection of organized, interrelated data, typically relating to a particular enterprise
  - A *Database Management System* (DBMS) is a set of programs for managing and accessing databases

Some Popular Database Management Systems

- Commercial "off-the-shelf" (COTS):
  - Oracle
  - IBM DB2 (IBM)
  - SQL Server (Microsoft)
  - Sybase
  - Informix (IBM)
  - Access (Microsoft)
  - Cache (Intersystems – nonrelational)
- Open Source:
  - MySQL
  - PostgreSQL

Note: This is not a course on any particular DBMS!

Some Database Applications

- Anywhere there is data, there could be a database:
  - Banking - accounts, loans, customers
  - Airlines - reservations, schedules
  - Universities - registration, grades
  - Sales - customers, products, purchases
  - Manufacturing - production, inventory, orders, supply chain
  - Human resources - employee records, salaries, tax deductions
- Course context is an “enterprise” that has requirements for:
  - Storage and management of 100’s of gigabytes or terabytes of data
  - Support for 100’s or more of concurrent users and transactions
  - Traditional supporting platform, e.g, Dell PowerEdge R720xd, 68 processors, 16GB RAM each, 50TB of disk space

Purpose of Database System

- Prior to the availability of COTS DBMSs, database applications were built on top of file systems – coded from the ground up.

- Drawbacks of this approach:
  - Difficult to reprogram sophisticated processing, i.e., concurrency control, backup and recovery, security
  - Re-inventing the wheel can be expensive and error-prone.
  - “We need a truck, lets design and build our own truck.”***

- According to the book, this leads to:
  - Data redundancy and inconsistency
  - Multiple files and formats
  - A new program to carry out each new task
  - Integrity constraints (e.g. account balance > 0) become embedded throughout program code, etc.

- Database systems offer proven solutions for the above problems.

Purpose of Database Systems (Cont.)

- Even to this day, engineers will occasionally propose custom-developed file systems.

- So when should we code from scratch, and when do we buy a DBMS??
  - How much data?
  - How sophisticated is the processing of that data?
  - How many concurrent users?
  - What level of security?
  - Is data integrity an issue?
  - Does the data change at all?

Concept #2: Levels of Abstraction

Levels of Abstraction

- Physical level - defines low-level details about how data item is stored on disk.
- Logical level - describes data stored in a database, and the relationships among the data (usually conveyed as a data model, e.g., an ER diagram).
- View level - defines how information is presented to users. Views can also hide details of data types, and information (e.g., salary) for security purposes.

Levels of Abstraction

- *Physical data independence* is the ability to modify the physical schema without having an impact on the logical or view levels.
- Physical data independence is important in any database or DBMS.
- Similarly one could define *logical data independence*, but that would not be as meaningful.

Concept #3: Instances vs. Schemas

Instances vs. Schemas

- The difference between a *database schema* and a *database instance* is similar to the difference between a data type and a variable in a program.
- A database *schema* defines the structure or design of a database.
- More precisely:
  - A *logical* schema defines a database design at the logical level; typically an entity-relationship (ER) or UML diagram.
  - A *physical* schema defines a database design at the physical level; typically a DDL file.
- An *instance* of a database is the combination of the database and its' contents at one point in time.

Concept #4: Data Models

What is a Data Model?

- The phrase *"data model"* is used in a couple of different ways.
- Frequently used (use #1) to refer to an overall approach or philosophy for database design and development.
- For those individuals, groups and corporations that subscribe to a specific data model, that model permeates all aspects of database design, development, implementation, etc.

What is a Data Model?

- Common data models:
  - Relational model
  - Object-oriented model
  - Object-relational model
  - Semi, and non-structured data models (XML)
  - Various other NoSQL models (graph, document, key/value)
- Legacy data models:
  - Network
  - Hierarchical

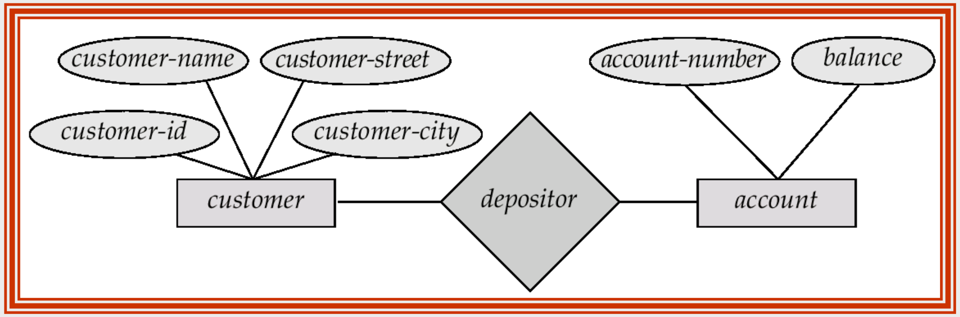
What is a Data Model, Cont?

- During the early phases of database design and development, a *"data model"* is frequently developed (use #2).
- The purpose of developing the data model is to define:
  - Data
  - Relationships between data items
  - Semantics of data items
  - Constraints on data items

  In other words, a data model defines the logical schema, i.e., the logical level of design of a database.
- A data model is typically conveyed as one or more diagrams (e.g., ER or UML diagrams).
- This early phase in database development is referred to as *data modeling*.

Entity-Relationship Diagrams

- Examples of entity-relationship diagrams:
  - Authors current (UML-ish) notation:
    - http://my.fit.edu/~pbernhar/Teaching/DatabaseSystems/Slides/University.pdf
  - Older (Chen) notation:



- Widely used for database modeling.

A Sample Relational Database

- Regardless of the model, the end result is the same – a relational database consisting of a collection of tables:

customer-id	*customer-name*	*customer-street*	*customer-city*
192-83-7465	Johnson	12 Alma St.	Palo Alto
019-28-3746	Smith	4 North St.	Rye
677-89-9011	Hayes	3 Main St.	Harrison
182-73-6091	Turner	123 Putnam Ave.	Stamford
321-12-3123	Jones	100 Main St.	Harrison
336-66-9999	Lindsay	175 Park Ave.	Pittsfield
019-28-3746	Smith	72 North St.	Rye

(a) The *customer* table

customer-id	*account-number*
192-83-7465	A-101
192-83-7465	A-201
019-28-3746	A-215
677-89-9011	A-102
182-73-6091	A-305
321-12-3123	A-217
336-66-9999	A-222
019-28-3746	A-201

(c) The *depositor* table

account-number	*balance*
A-101	500
A-215	700
A-102	400
A-305	350
A-201	900
A-217	750
A-222	700

(b) The *account* table

Concept #5: Query Languages

Query Languages

- A ***query language*** is used to create, manage, access, and modify data in a database.

- The list of query languages is quite long:
  - http://en.wikipedia.org/wiki/Query_languages

- The most widely used query language is ***Structure Query Language*** *(SQL).*

- At a high-level, SQL consists of two parts:
  - *Data Definition Language* (DDL)
  - *Data Manipulation Language* (DML)

Data Definition Language (DDL)

- DDL is used for defining a (physical) database schema (see the book for a more complete example):

```
create table account (
   account-number        char(10),
   branch-name           varchar(16),
   balance               integer,
   primary key (account-number))
```

- Given a DDL file, the DDL compiler generates a set of tables.
- The authors also define a subset of DDL called *Data storage and definition language* for specifying things such as:
  - Location on disk
  - Physical-level formatting
  - Access privledges

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Data Manipulation Language (DML)

- DML is used for accessing and manipulating a database.
- Two classes of DMLs:
  - *Procedural* – user specifies how to get the required data.
  - *Non-procedural* – user specifies what data is required, but not how to get that data.
- SQL is usually referred to as a non-procedural query language.

SQL Examples

- Find the name of the customer with customer-id 192-83-7465:

  select *customer.customer-name*
  from *customer*
  where *customer.customer-id* = '192-83-7465'

- Find the balances of all accounts held by the customer with customer-id 192-83-7465:

  select *account.balance*
  from *depositor*, *account*
  where *depositor.customer-id* = '192-83-7465' **and**
  depositor.account-number = *account.account-number*

- Databases are typically accessed by:
  - Users through a command line interface
  - Users through a query or software editing tool, e.g., MySQL Workbench
  - Application programs that (generally) access them through embedded SQL or an application program interface (e.g. ODBC/JDBC)

Concept #6: Database Users

Database Users

Users are differentiated by the way they interact with the system:

- *Naïve users*
- *Application programmers*
- *Specialized users*
- *Sophisticated users*

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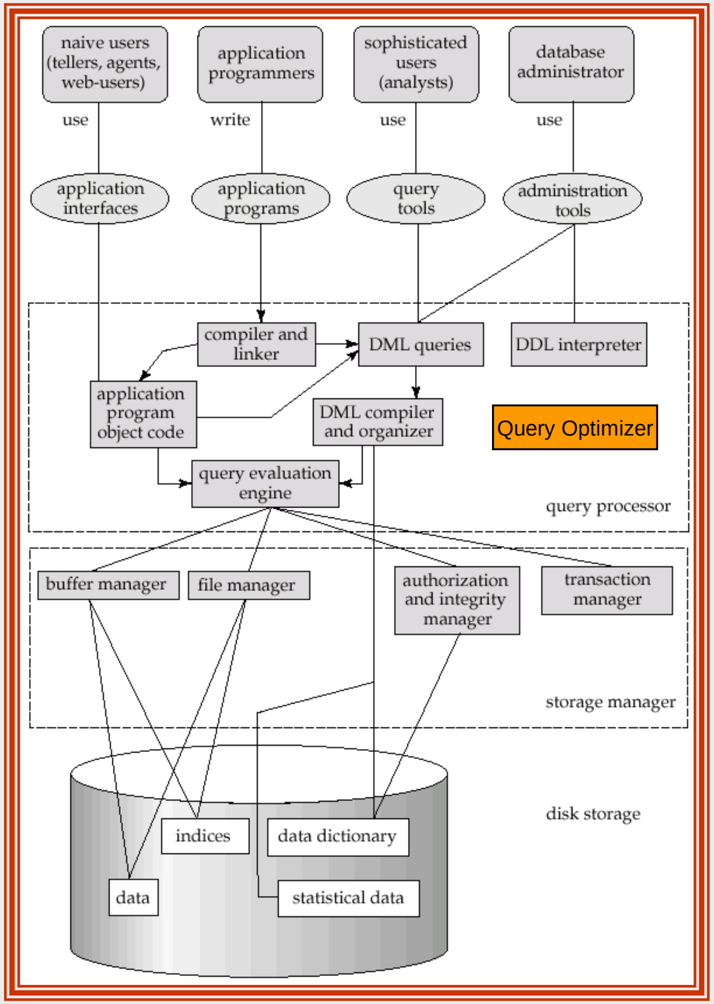
Database Administrator (DBA)

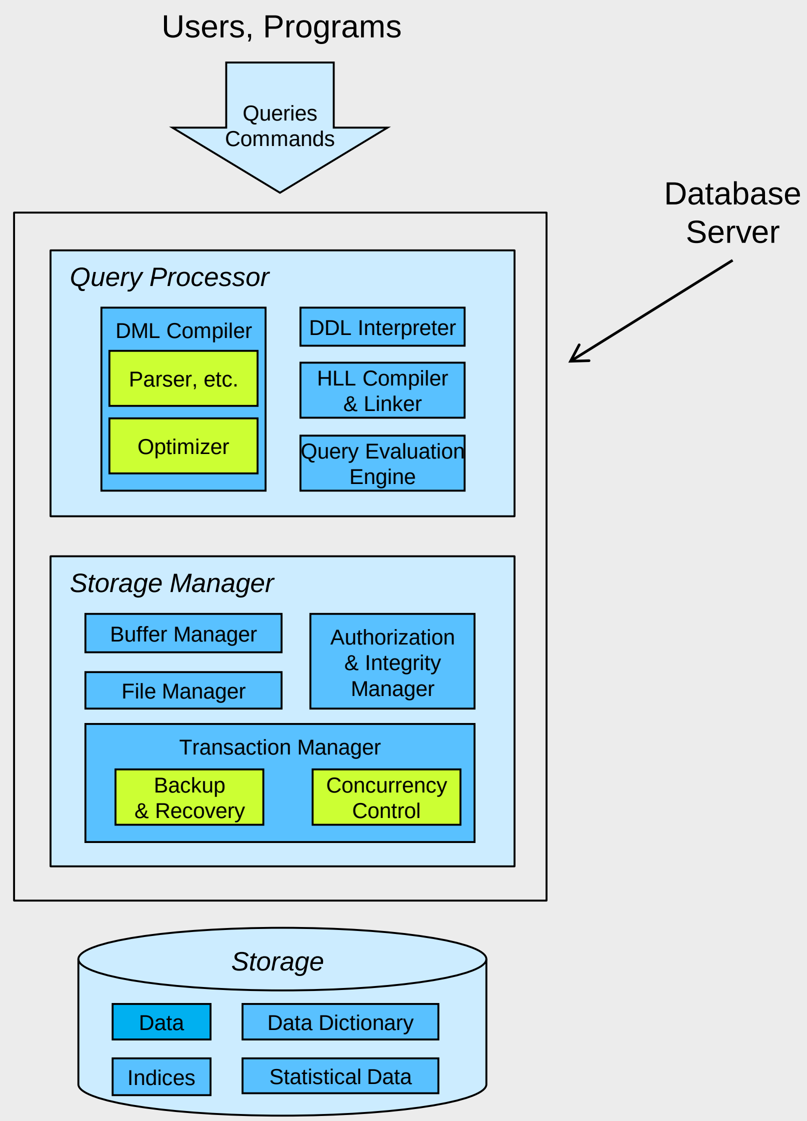
- The DBA coordinates all the activities of the database system; has a good understanding of the enterprise's information resources and needs.
- DBA duties:
  - Granting user authority to access the database
  - Acting as liaison with users
  - Installing and maintaining DBMS software
  - Monitoring performance and performance tuning
  - Backup and recovery
- According to the book, the DBA is also responsible for:
  - Logical and Physical schema definition and modification
  - Access method definition
  - Specifying integrity constraints
  - Responding to changes in requirements
- These latter tasks are frequently performed by a software or systems engineer specialized in database design.

Concept #7: DBMS Structure

Overall DBMS Structure



Overall DBMS Structure



Overall DBMS Structure

The following components of a DBMS are of interest to us:

- transaction manager
- buffer manager
- file manager
- authorization and integrity manager
- query optimizer

Transaction Management

- A *transaction* is a collection of operations that performs a single logical function in a database application
- The *transaction manager* performs two primary functions:
  - backup and recovery
  - concurrency control
- *Backup and recovery* ensures that the database remains in a consistent (correct) state despite failures:
  - system, power, network failures
  - operating system crashes
  - transaction failures.
- *Concurrency-control* involves managing the interactions among concurrent transactions.

Storage Management

- The *buffer manager* loads data into main memory from disk as it is needed by the DBMS, and writes it back out when necessary.

- The buffer manager is responsible for:
  - loading pages of data from disk into a segment of main memory called “the buffer”; a.k.a. “the cache”
  - determining which pages in the buffer get replaced
  - writing pages back out to disk
  - managing overall configuration of the buffer, decomposition into memory pools, page time-stamps, etc.

- Sound familiar?

Storage Management

- The ***file manager*** is responsible for managing the files that store data.
  - formatting the data files
  - managing free and used space in the data files
  - defragmenting the data files
  - inserting and deleting specific data from the files

Authorization & Integrity Management

- The *authorization & integrity manager* performs two primary functions:
  - data security
  - data integrity

- Data security:
  - ensure that unauthorized users can't access the database
  - ensure that authorized users can only access appropriate data

- Data integrity:
  - in general, maintains & enforces integrity constraints
  - maintains data relationships in the presence of data modifications
  - prevents modifications that would corrupt established data relationships

Query Optimization

- A given query can be implemented by a DBMS in many different ways.
- The *query optimizer* attempts to determine the most efficient strategy for executing a given query.
- The strategy for implementing a given query is referred to as a *query plan*.

