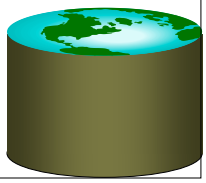
CS186 - Introduction to Database Systems

Spring Semester 2003
Prof. Joe Hellerstein

"Knowledge is of two kinds: we know a subject ourselves, or we know where we can find information upon it."
-- Samuel Johnson (1709-1784)



What Is a Database *System*?

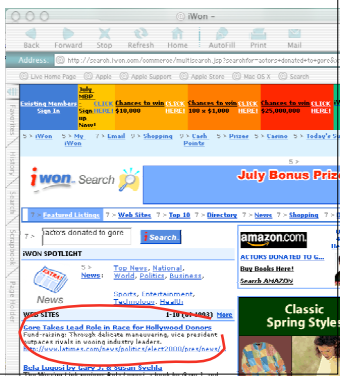
- **Database:**
  a very large, integrated collection of data.
- **Models a real-world *enterprise***
  - Entities (e.g., teams, games)
  - Relationships
    (e.g., The Raiders *are playing in* The Superbowl)
  - More recently, also includes active components
    (e.g. "business logic")
- **A *Database Management System (DBMS)* is a software system designed to store, manage, and facilitate access to databases.**

Is the WWW a DBMS?

- **Fairly sophisticated search available**
  - crawler *indexes* pages on the web
  - Keyword-based search for pages
- **But, currently**
  - data is mostly unstructured and untyped
  - search only:
    - can't modify the data
    - can't get summaries, complex combinations of data
  - few guarantees provided for freshness of data, consistency across data items, fault tolerance, ...
  - Web sites (e.g. e-commerce) typically have a DBMS in the background to provide these functions.
- **The picture is changing**
  - New standards like XML can help data modeling
  - Research groups (like ours at Berkeley) are working on providing some of this functionality *across multiple web sites.*
  - The WWW/DB boundary is blurring!

"Search" vs. Query

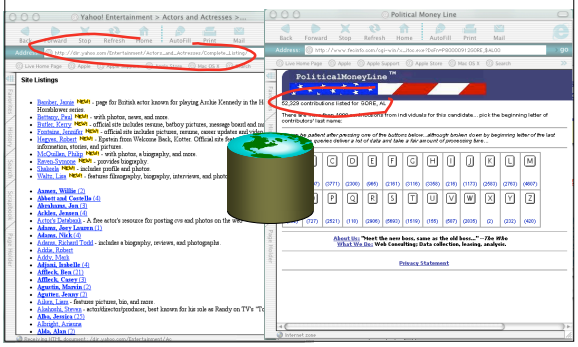
- **What if you wanted to find out which actors donated to Al Gore's presidential campaign?**
- **Try "actors donated to gore" in your favorite search engine.**



"Search" vs. Query

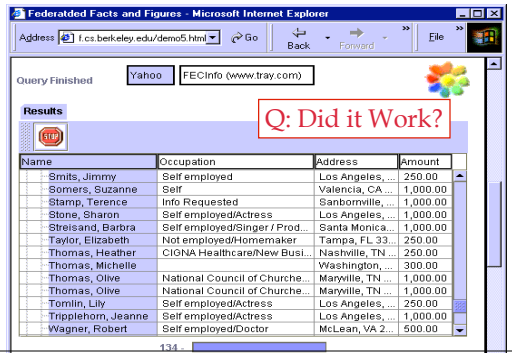
- **"Search" can return only what's been "stored"**
- **E.g., best match at iWon, Google, AskJeeves top ten:**

A "Database Query" Approach



"Yahoo Actors" JOIN "FECInfo"

(Courtesy of the Telegraph research group @Berkeley)



Is a File System a DBMS?

- **Thought Experiment 1:**
  - You and your project partner are editing the same file.
  - You both save it at the same time.
  - Whose changes survive?

A) Yours B) Partner's C) Both D) Neither E) ???

- **Thought Experiment 2:**
  - You're updating a file.
  - The power goes out.
  - Which of your changes survive?

A) All B) None C) All Since last save D) ???

Q: How do you write programs over a subsystem when it promises you only "???" ?

A: Very, very carefully!!

Why Study Databases??

- **Shift from *computation* to *information***
  - always true for corporate computing
  - Web made this point for personal computing
  - more and more true for scientific computing
- **Need for DBMS has exploded in the last years**
  - Corporate: retail swipe/clickstreams, "customer relationship mgmt", "supply chain mgmt", "data warehouses", etc.
  - Scientific: digital libraries, Human Genome project, NASA Mission to Planet Earth, physical sensors, grid physics network
- **DBMS encompasses much of CS in a practical discipline**
  - OS, languages, theory, AI, multimedia, logic
  - Yet traditional focus on real-world apps

What's the intellectual content?

- **representing information**
  - data modeling
- **languages and systems for querying data**
  - complex queries with real *semantics**
  - over massive data sets
- ***concurrency control* for data manipulation**
  - controlling concurrent access
  - ensuring *transactional semantics*
- **reliable data storage**
  - maintain data semantics even if you pull the plug

* semantics: the meaning or relationship of meanings of a sign or set of signs

About the course: Enrollment

- **Overenrollment again across CS**
  - The CS dept administration "makes the call"
  - TA's & Prof. cannot help!!
  - Course is overbooked, drops won't free space
  - Want to appeal?
    - See http://www.cs.berkeley.edu/~msasson/enrollment.html for more info
    - Appeal forms need to be in by 1/25
- **CS186 is planned for Every Semester**
  - Your priority goes up over time

About the course: Workload

- **Projects with a "real world" focus:**
  - Modify the internals of a "real" open-source database system: PostgreSQL
    - Serious C system hacking
    - Measure the benefits of our changes
  - Build a web-based e-commerce application w/PostgreSQL, Apache & PHP): SQL + PHP
- **Other homework assignments and/or quizes**
- **Exams – 1 Midterm & 1 Final**
- **Projects to be done in groups of 3**
  - Pick your partners ASAP
- **The course is "front-loaded"**
  - most of the hard work is in the first half

About the Course - Administrivia

- **http://inst.eecs.berkeley.edu/~cs186**
- **Prof. Office Hours:**
  - 685 Soda Hall, M 2-3; Tues 11-12 (tentative!)
- **TAs: Zhuang Li, Boon Thau Loo, Sailesh Krishnamurthy**
  - Office Hours: TBA (check web page)
- **Discussion Sections WILL meet this week**
  - Note change to discussion section schedule!

About the Course - Administrivia

- **Textbook**
  - Ramakrishnan and Gehrke, 3rd Edition
- **Grading, hand-in policies, etc. will be on Web Page**
- **Cheating policy: zero tolerance**
  - We have the technology…
- **Team Projects**
  - Teams of 3, if one drops the other 2 finish it up
  - Peer evaluations.
    - Be honest! Feedback is important. Trend is more important than individual project.
- **Class bulletin board - ucb.class.cs186**
  - read it regularly and post questions/comments.
  - mail broadcast to all TAs will not be answered
  - mail to the cs186 course account will not be answered
    - It's a spam disposal site

Rest of Today: A CS186 Infomercial

- **A "free tasting" of things to come in this class:**
  - data modeling
  - query languages
  - file systems & DBMSs
  - concurrent, fault-tolerant data management
  - DBMS architecture
- **Next Time**
  - The Relational Model
- **Today's lecture is from Chapter 1 in R&G**

OS Support for Data Management

- **Data can be stored in RAM**
  - this is what every programming language offers!
  - RAM is fast, and random access
  - Isn't this heaven?
- **Every OS includes a File System**
  - manages *files* on a magnetic disk
  - allows *open, read, seek, close* on a file
  - allows protections to be set on a file
  - drawbacks relative to RAM?

Database Management Systems

- **What more could we want than a file system?**
  - Simple, efficient *ad hoc*[1] queries
  - concurrency control
  - recovery
  - benefits of good data modeling
- **S.M.O.P.[2]? Not really…**
  - as we'll see this semester
  - in fact, the OS often gets in the way!

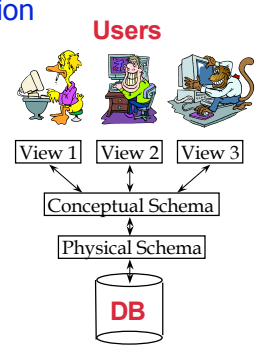
[1] ad hoc: formed or used for specific or immediate problems or needs
[2] SMOP: Small Matter Of Programming

Describing Data: Data Models

- **A *data model* is a collection of concepts for describing data.**
- **A *schema* is a description of a particular collection of data, using a given data model.**
- **The *relational model of data* is the most widely used model today.**
  - Main concept: *relation*, basically a table with rows and columns.
  - Every relation has a *schema*, which describes the columns, or fields.

Levels of Abstraction

- Views describe how users see the data.
- Conceptual schema defines logical structure
- Physical schema describes the files and indexes used.
- (sometimes called the ANSI/SPARC model)



Example: University Database

- **Conceptual schema:**
  - *Students(sid: string, name: string, login: string, age: integer, gpa:real)*
  - *Courses(cid: string, cname:string, credits:integer)*
  - *Enrolled(sid:string, cid:string, grade:string)*
- **Physical schema:**
  - Relations stored as unordered files.
  - Index on first column of Students.
- **External Schema (View):**
  - *Course_info(cid:string,enrollment:integer)*

Data Independence

- **Applications insulated from how data is structured and stored.**
- **Logical data independence: Protection from changes in *logical* structure of data.**
- **Physical data independence: Protection from changes in *physical* structure of data.**
- **Q: Why is this particularly important for DBMS?**

Because rate of change of DB applications is incredibly slow.
More generally:
dapp/dt << dplatform/dt

Concurrency Control

- **Concurrent execution of user programs: key to good DBMS performance.**
  - Disk accesses frequent, pretty slow
  - Keep the CPU working on several programs concurrently.
- **Interleaving actions of different programs: trouble!**
  - e.g., account-transfer & print statement at same time
- **DBMS ensures such problems don't arise.**
  - Users/programmers can pretend they are using a single-user system. (called "Isolation")
  - Thank goodness! Don't have to program "very, very carefully".

Transaction: An Execution of a DB Program

- **Key concept is a transaction: an atomic sequence of database actions (reads/writes).**
- **Each transaction, executed completely, must take the DB between consistent states.**
- **Users can specify simple integrity constraints on the data. The DBMS enforces these.**
  - Beyond this, the DBMS does not understand the semantics of the data.
  - Ensuring that a single transaction (run alone) preserves consistency is ultimately the user's responsibility!

Scheduling Concurrent Transactions

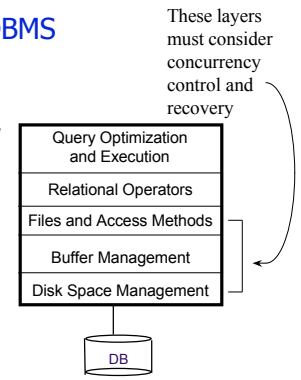
- **DBMS ensures that execution of {T1, … , Tn} is equivalent to some *serial* execution T1' … Tn'.**
  - Before reading/writing an object, a transaction requests a lock on the object, and waits till the DBMS gives it the lock.
    All locks are held until the end of the transaction.
    (Strict 2PL locking protocol.)
  - Idea: If an action of Ti (say, writing X) affects Tj (which perhaps reads X),
    … say Ti obtains the lock on X first
    … so Tj is forced to wait until Ti completes.
    This effectively orders the transactions.
  - What if
    … Tj already has a lock on Y
    … and Ti later requests a lock on Y?
    (Deadlock!) Ti or Tj is aborted and restarted!

Ensuring Transaction Properites

- **DBMS ensures *atomicity* (all-or-nothing property) even if system crashes in the middle of a Xact.**
- **DBMS ensures *durability* of *committed* Xacts even if system crashes.**
- **Idea: Keep a *log* (history) of all actions carried out by the DBMS while executing a set of Xacts:**
  - Before a change is made to the database, the corresponding log entry is forced to a safe location. (*WAL protocol*; OS support for this is often inadequate.)
  - After a crash, the effects of partially executed transactions are *undone* using the log. Effects of committed transactions are *redone* using the log.
  - trickier than it sounds!

Structure of a DBMS

- **A typical DBMS has a layered architecture.**
- **The figure does not show the concurrency control and recovery components.**
- **Each system has its own variations.**
- **The book shows a somewhat more detailed version.**
- **You will see the "real deal" in PostgreSQL.**
  - It's a pretty full-featured example



Advantages of a DBMS

- **Data independence**
- **Efficient data access**
- **Data integrity & security**
- **Data administration**
- **Concurrent access, crash recovery**
- **Reduced application development time**
- **So why not use them always?**
  - Expensive/complicated to set up & maintain
  - This cost & complexity must be offset by need
  - General-purpose, not suited for special-purpose tasks (e.g. text search!)

Databases make these folks happy ...

- **DBMS vendors, programmers**
  - Oracle, IBM, MS, Sybase, NCR, …
- **End users in many fields**
  - Business, education, science, …
- **DB application programmers**
  - Build enterprise applications on top of DBMSs
  - Build web services that run off DBMSs
- **Database administrators (DBAs)**
  - Design logical/physical schemas
  - Handle security and authorization
  - Data availability, crash recovery
  - Database tuning as needs evolve

…must understand how a DBMS works

Summary (part 1)

- **DBMS used to maintain, query large datasets.**
  - can manipulate data and exploit *semantics*
- **Other benefits include:**
  - recovery from system crashes,
  - concurrent access,
  - quick application development,
  - data integrity and security.
- **Levels of abstraction provide data independence**
  - Key when *dapp/dt << dplatform/dt*
- **In this course we will explore:**
  1) How to be a sophisticated user of DBMS technology
  2) What goes on inside the DBMS

Summary, cont.

- DBAs, DB developers the bedrock of the information economy

- DBMS R&D represents a broad, fundamental branch of the science of computation