Database Management Systems

Fall 2016

"Knowledge is of two kinds: we know a subject ourselves, or we know where we can find information upon it."

-- Samuel Johnson (1709-1784)

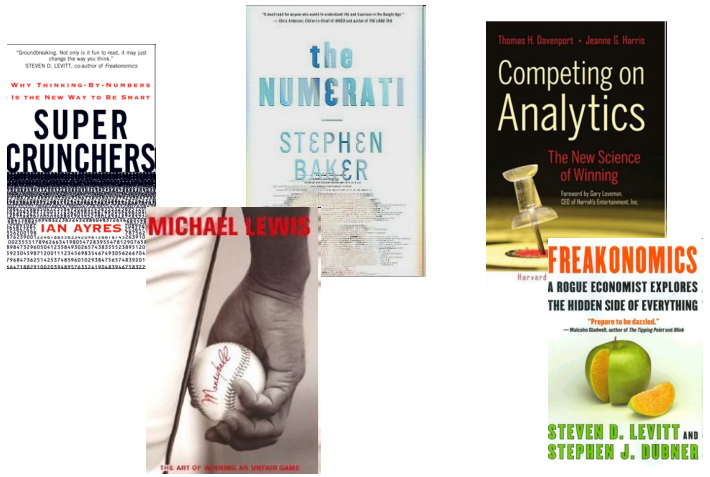
Queries for Today

- **Why?**
- Who?
- What?
- How?
- For instance?

Databases – Why Study Them?

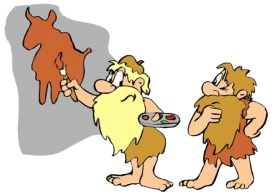
The quest for knowledge used to begin with grand theories.
Now it begins with massive amounts of data.
Welcome to the Petabyte Age.

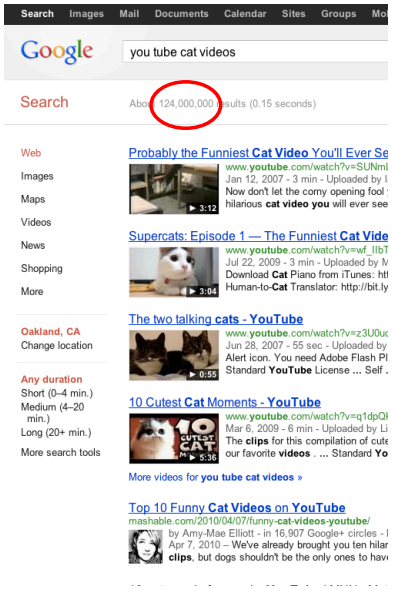
Databases – Why Study Them?

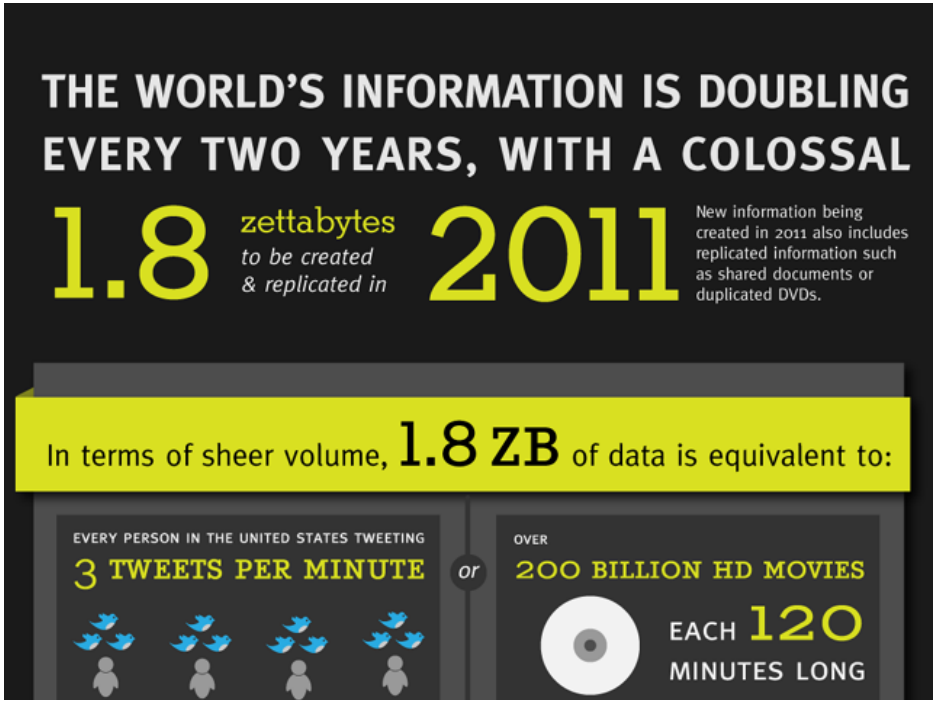


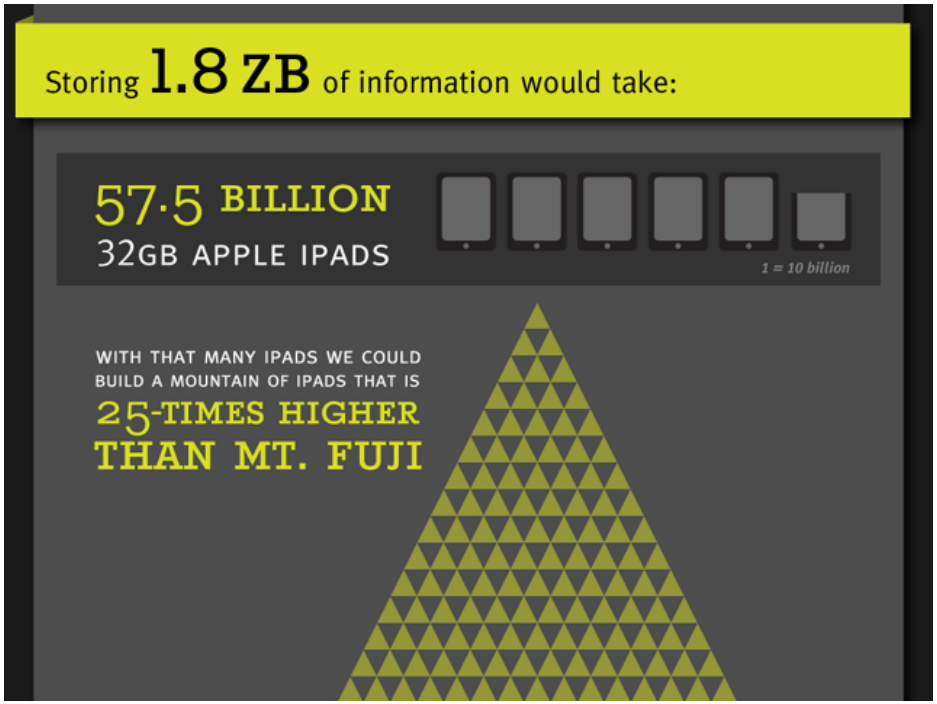
The “Big Data” Buzz – Why?

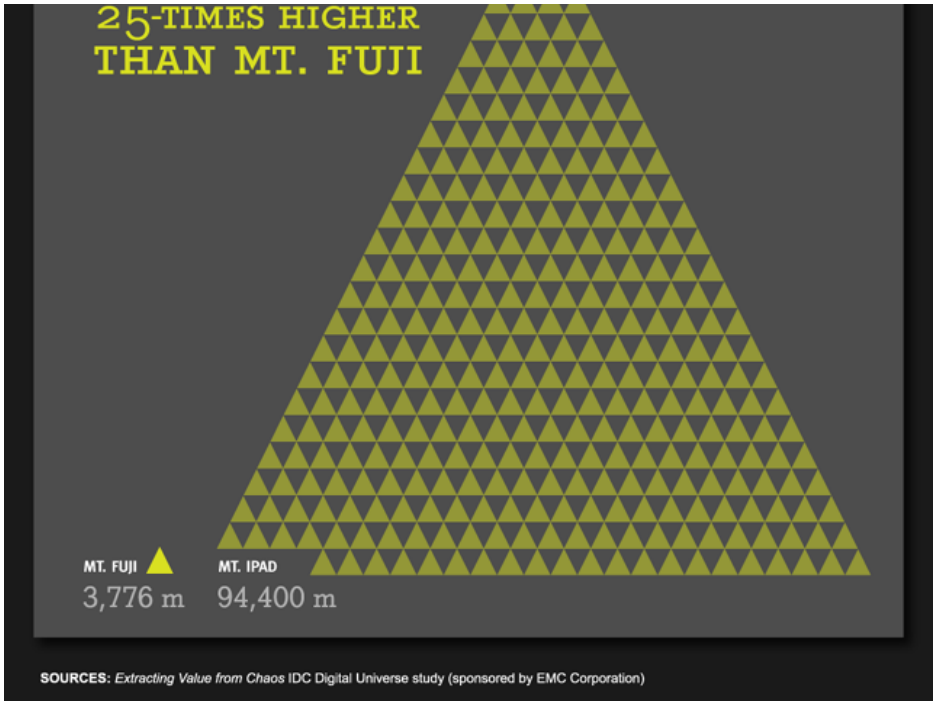
“Between the dawn of civilization and 2003, we only created five exabytes of information; now we’re creating that amount every two days.” Eric Schmidt, Google (and others)



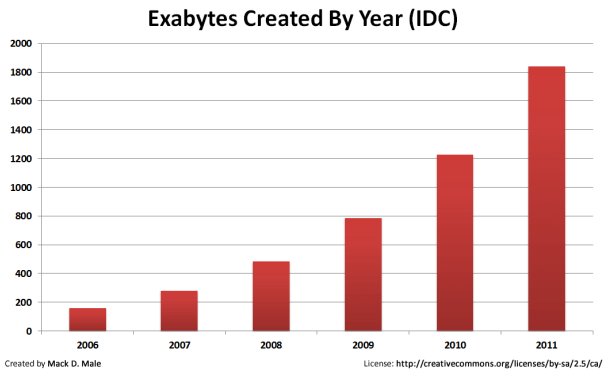








The "Big Data" Buzz – Why?

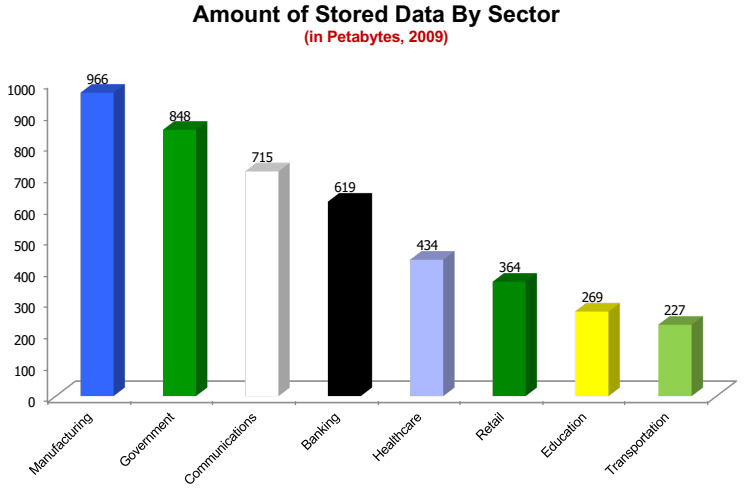


SI decimal prefixes		Binary usage
Name (Symbol)	Value	
kilobyte (kB)	10^3	2^{10}
megabyte (MB)	10^6	2^{20}
gigabyte (GB)	10^9	2^{30}
terabyte (TB)	10^{12}	2^{40}
petabyte (PB)	10^{15}	2^{50}
exabyte (EB)	10^{18}	2^{60}
zettabyte (ZB)	10^{21}	2^{70}
yottabyte (YB)	10^{24}	2^{80}

"The sexy job in the next 10 years will be statis~~ticians~~." "Data Scientists"?

Hal Varian
Prof. Emeritus UC Berkeley
Chief Economist, Google

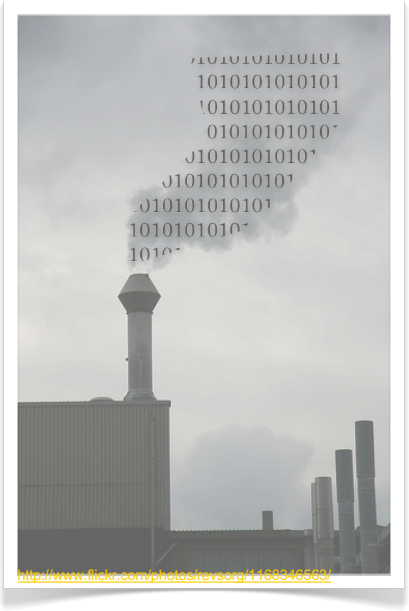
Some Numbers by Industry



Sources:
"Big Data: The Next Frontier for Innovation, Competition and Productivity."
US Bureau of Labor Statistics | McKinsey Global Institute Analysis

Industrial Revolution of Data!

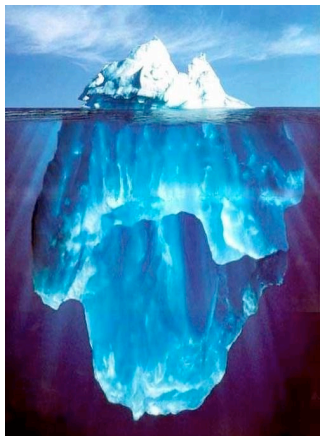
- **UPC**
- **RFID**
- **GPS**
- **Sensornets**
- **Software Logs**
- **Microphones**
- **Cameras**
- **…**



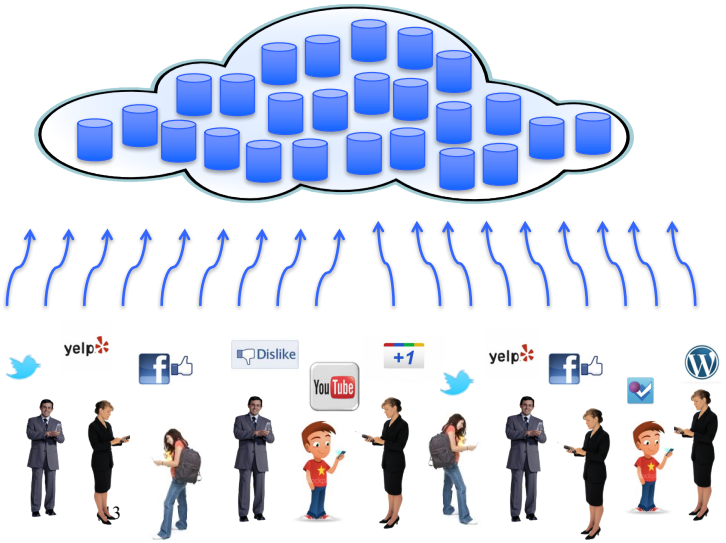
http://www.flickr.com/photos/revsorg/4168346563/

It's All Happening On-line

- **Every:**
  - Click
  - Ad impression
  - Wall post, friending, …
  - Billing event
  - Fast Forward, pause,…
  - Server request
  - Transaction
  - Network message
  - Fault
  - …
- **Generates Streams of Data that can be Analyzed**



User Generated Content



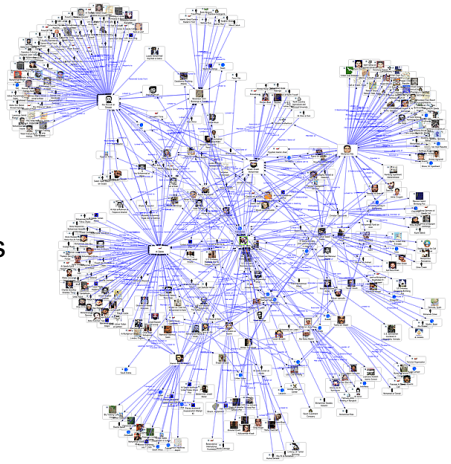
Credit: Mike Carey, UCI

Graph Data

Lots of interesting data has a graph structure:

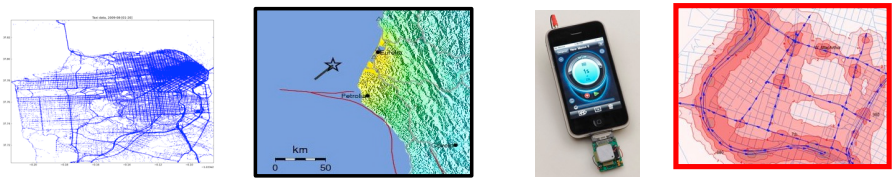
- Social networks
- Communication networks
- Computer Networks
- Road networks
- Citations
- Collaborations/Relationships
- …

Some of these graphs can get quite large (e.g., Facebook's user graph)



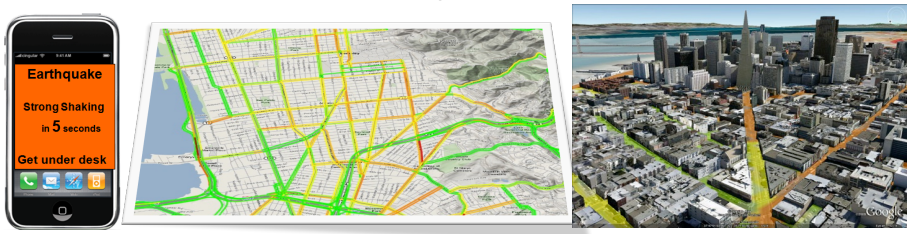
M2M - Internet of things

Fusion: e.g., NextGen Maps



Crowdsourcing + physical modeling + sensing + data assimilation

to produce:



From Alex Bayen, UCB

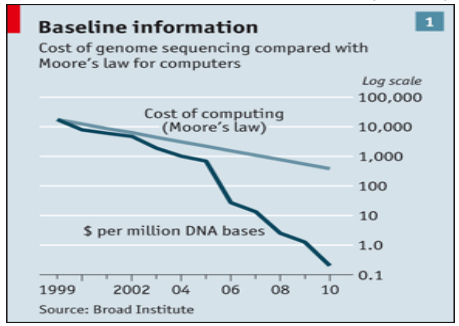
What can you do with the data

- **Reporting**
  - Post Hoc
  - Real time
- **Monitoring (fine-grained)**
- **Exploration**
- **Finding Patterns**
- **Root Cause Analysis**
- **Closed-loop Control**
- **Model construction**
- **Prediction**
- **…**

Big Data, Societal-Scale App?

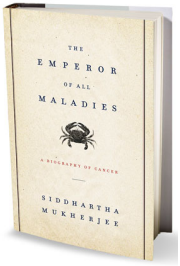
- **Cancer Tumor Genomics**
- **Vision: Personalized Therapy**
  - "…10 years from now, each cancer patient is going to want to get a genomic analysis of their cancer and will expect customized therapy based on that information."

Director, The Cancer Genome Atlas (TCGA), *Time Magazine,* 6/13/11



Opportunity or Obligation?

- Provocative Hypothesis: Given fast growing genomic databases, could CS now be a huge help in war on cancer?
- If a *chance* that we could help millions of cancer patients live longer and better lives, as moral people, aren't we obligated to try?



David Patterson, "Computer Scientists May Have What It Takes to Help Cure Cancer," *New York Times*, 12/5/2011

• UCSF cancer researchers + UCSC cancer genetic database + AMP Lab

The Cancer Genome Atlas: 5 PB = 20 cancers x 1000 genomes

So, In Summary…Why?

Data will be at the center of the major issues and events of your life.

As a computer professional, you'd better be on top of how to manage, use, and make sense of it.

Who?

- **Haidar M. Harmanani**
  - Professor of Computer Science
  - Office: 810 Block A
  - Office Hours: TTh: 8:00-9:30 and 3:00-4:30
  - Email: haidar@lau.edu.lb
- **Course Website:**
  - http://vlsi.byblos.lau.edu.lb/classes/csc375/csc375.html

Queries for Today

- Why?
- Who?
- **What?**
- How?
- For instance?

What is a Database?

[The Relational Model] provides a basis for a high level data language which will yield maximal independence between programs on the one hand and machine representation on the other. (E.F. Codd, *1981 Turing Award winner*)

In Other Words…

Relational DataBase Management Systems were invented to let you use one set of data in multiple ways, including ways that are unforeseen at the time the database is built and the 1st applications are written.

(Curt Monash, analyst/blogger)

That is, think about the data independently of any particular program.

What is a Database?

- **Let's not split hairs.**

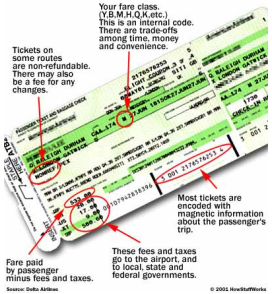
A *database* is a large collection of structured data

What is a DBMS?

A *Database Management System (DBMS)* is software that stores, manages and/or facilitates access to databases.

- **Traditionally, term used narrowly**
  - Relational databases with transactions
- **Warning: market and terms in rapid transition**
  - The tech remains (roughly) the same
  - Good time to focus on fundamentals!

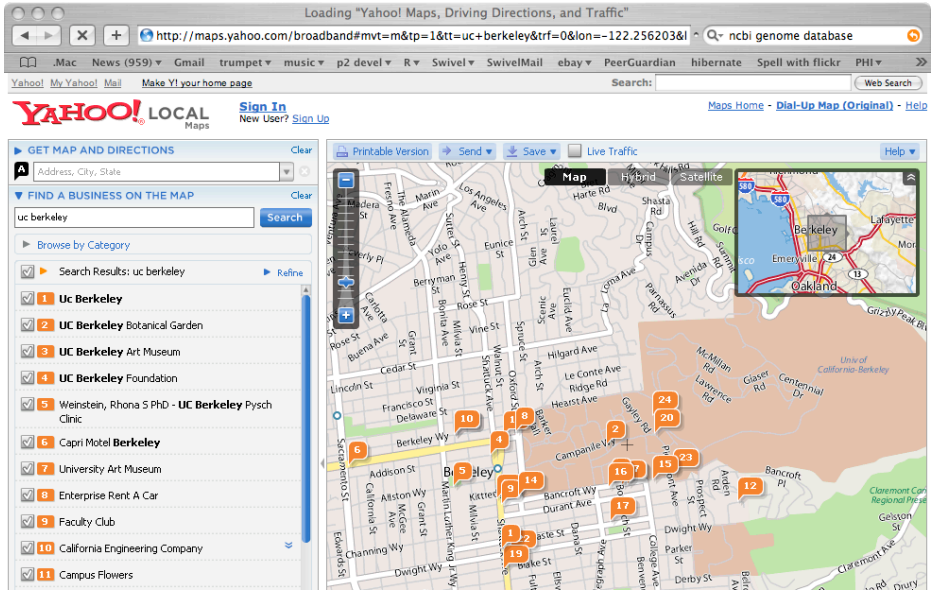
Some Ways you May Use Databases



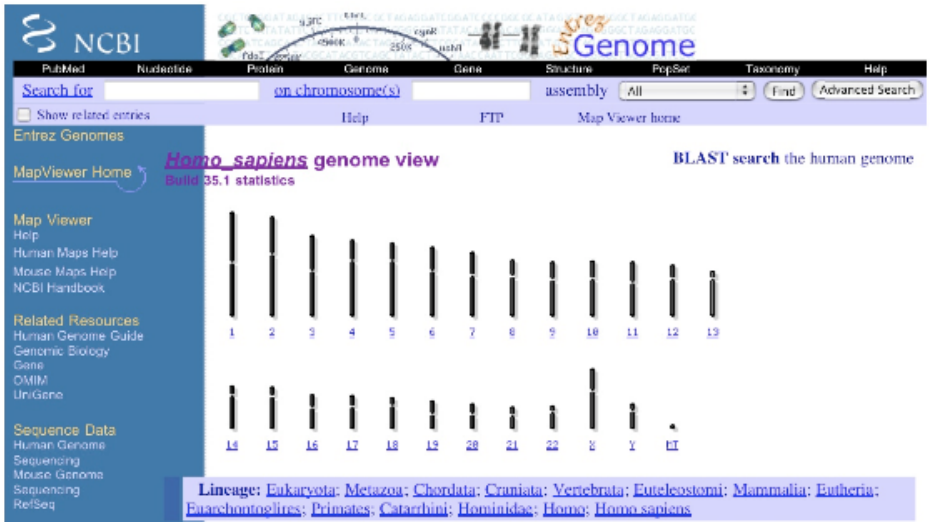
amazon.com

Find the Database(s) in This Picture

Other Kinds of Databases (spatial)



Other Kinds of Databases (genome)



Databases Make Life Better?

- **"Players could finally sign up for the Star Wars Galaxies game last week as Sony opened up registration to the public."**

- **"Once players got in to the game they found that the game servers were offline because of database problems."**
- **"Some players spent hours tuning their in-game characters only to find that crashes deleted all their hard work."**

Source: BBC News Online, July 1, 2003.

What: Is an OS a DBMS?

- **Data can be stored in RAM**
  - every programming language offers this
  - RAM is fast, and random access
  - isn't this heaven?

What: Is an OS a DBMS?

- **Data can be stored in RAM**
  - every programming language offers this
  - 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?

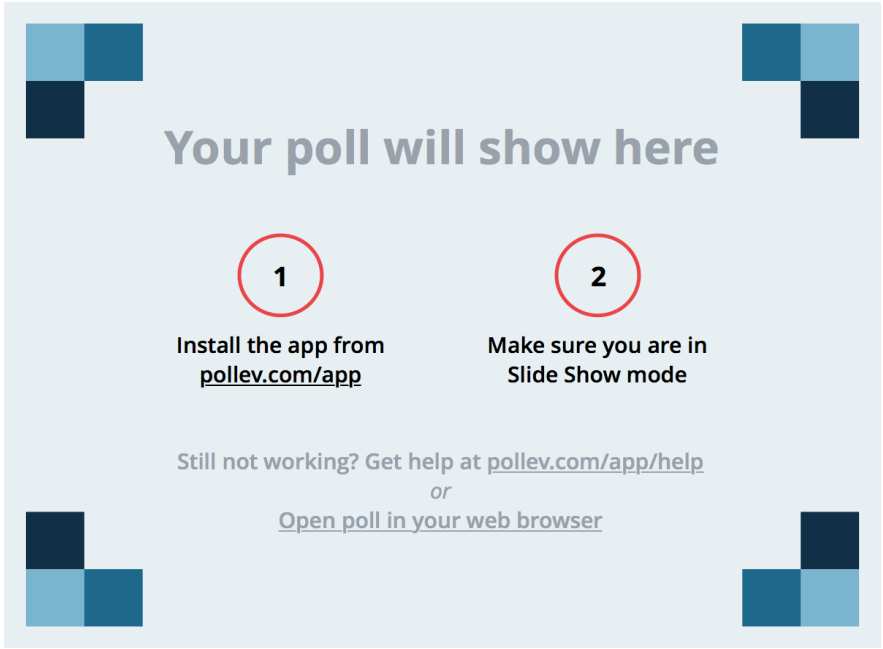
What: File System vs DBMS

- **Thought Experiment 1:**
  - You're updating a file.
  - The power goes out.
  - Which changes survive?

a) all
b) none
c) all since last save
d) ???

- **Answer to: PollEv.com/harmanani765**

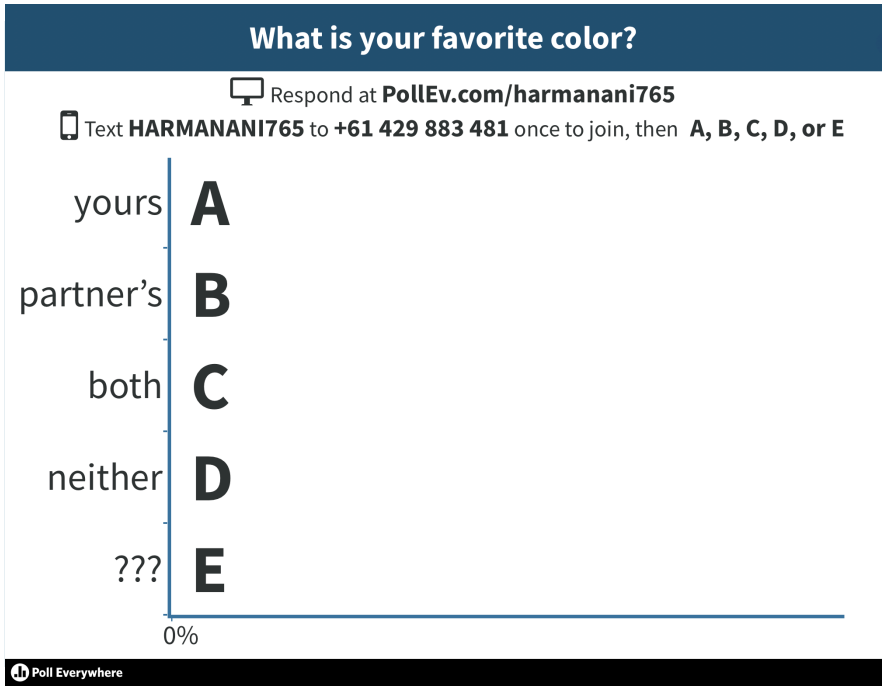
What: File System vs DBMS



What: File System vs DBMS

- **Thought Experiment 2:**
  - You and your project partner edit the same file.
  - You both save it at the same time.
  - Whose changes survive?

a) yours
b) partner's
c) both
d) neither
e) ???



What: File System vs DBMS

- **Thought Experiment 1:**
  - The power goes out.
  - Which changes survive?

Q: How do you code against an API that guarantees you "???" ?

A: *Very carefully.*

a) all
b) none
c) all since last save
d) ???

What: Database Systems

- **What more could we want than a file system?**
  - Clear *API contracts* regarding data
    - concurrency control, replication, recovery
  - Simple, efficient, well-defined *ad hoc*[1] queries
  - Efficient, scalable bulk processing
  - Benefits of good data modeling
- **S.M.O.P.[2]? Not really…**

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

What: Current Market

- **Relational DBMSs anchor the software industry**
  - Elephants: Oracle, IBM, Microsoft, Teradata, HP, EMC, …
  - Open source: MySQL, PostgreSQL
- **Obviously, Search**
  - Google & Bing
- **Open Source "NoSQL"**
  - Hadoop MapReduce
  - Key-value stores: Cassandra, Riak, Voldemort, Mongo, …
- **Cloud services**
  - Amazon, Google AppEngine, MS Azure, Heroku, …
- **Increasing use of custom code**

So…*What* Is a Database?

- **Database:**
  An (often) large, integrated collection of data.
- **Models a real-world *enterprise***
  - Entities (e.g., teams, games)
  - Relationships
    (e.g., Cal *plays against* Stanford *in* The Big Game)
  - Can also include active components , often called "business logic". (e.g., the BCS ranking system)

Key Concept: Structured Data

- 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.

Example: University Database

- **Conceptual schema:**
  Students(sid*: string,* name*: string,* age*: integer,* gpa*:real)*
  Courses(cid*: string,* cname*:string,* credits*:integer)*
  Enrolled(sid*:string,* cid*:string,* grade*:string)*
  FOREIGN KEY sid REFERENCES Students
  FOREIGN KEY cid REFERENCES Courses

- **External Schema (View):**
  Course_info(cid:string,enrollment:integer)
  Create View Course_info AS
  SELECT cid, Count (*) as enrollment
  FROM Enrolled
  GROUP BY cid

e.g.: An Instance of Students Relation

sid	name	login	age	gpa
53666	Jones	jones@cs	18	3.4
53688	Smith	smith@eecs	18	3.2
53650	Smith	smith@math	19	3.8

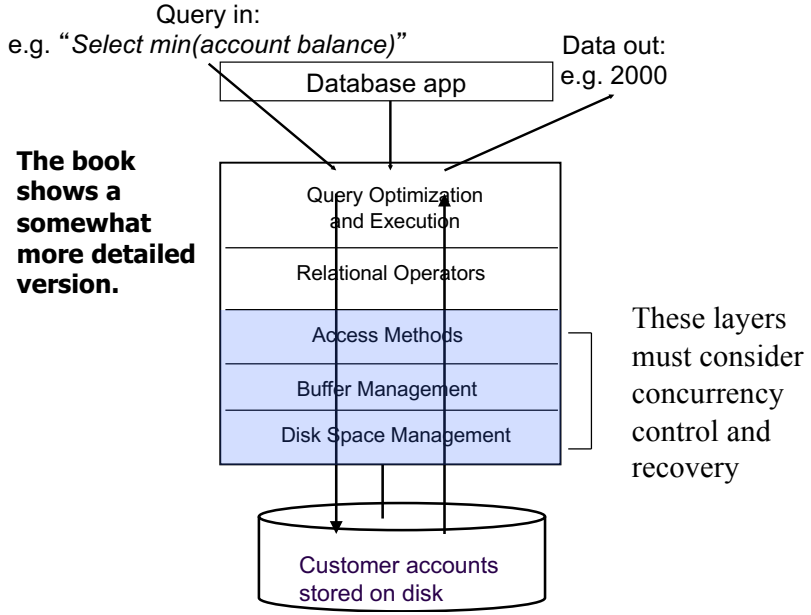
What is a Database System?

- **A *Database Management System (DBMS)* is a software system designed to store, manage, and facilitate access to databases.**

- **A DBMS provides:**
  - Data Definition Language (DDL)
  - Data Manipulation Language (DML)
    - Queries – to retrieve, analyze and modify data.
    - Sometimes called "CRUD"
  - Guarantees about durability, concurrency, semantics, etc.
- **Three main uses: Transactional, Archival, and Analytical**

A DBMS "Lasagna" Diagram

- **The book shows a somewhat more detailed version.**



What: Current Market

- **Relational DBMSs anchor the software industry**
  - Elephants: Oracle, IBM, Microsoft, Teradata, HP, EMC, …
  - Open source: MySQL, PostgreSQL
- **Obviously, Search**
  - Google & Bing
- **Open Source "NoSQL"**
  - Hadoop MapReduce
  - Key-value stores: Cassandra, Riak, Voldemort, Mongo, …
- **Cloud services**
  - Amazon, Google AppEngine, MS Azure, Heroku, …
- **Increasing use of custom code**

What will we learn?

- Design patterns for dealing with Big Data
- When, why and how to structure your data
- How MySQL and Oracle and (a bit of) Google work
- SQL ... and noSQL
- Managing concurrency
- Fault tolerance and Recovery
- Scaling out: parallelism and replication

- Audacity and Reverence.

What: Summing up

- Data is at the center of many things.
- For instance: computer science.

What: Summing up

You might think that we'll learn to apply computer science to Big Data.

The techniques we'll learn for Big Data are the key to scalable computer science.

Don't forget Hal Varian's prediction…

Google's Chief Economist

- **These professions barely have names:**
  - Cloud programmer
  - Data scientist
  - Scalable systems architect
  - Data-driven thinker
- **In 5 years, this will be a large fraction of the computing workforce.**

" By 2018, the US could face a shortage of up to 190,000 workers with analytical skills" McKinsey Global Institute