Welcome to

CS 460: Introduction to Database Systems

https://bu-disc.github.io/CS460/

Instructor: *Manos Athanassoulis*

email: mathan@bu.edu

Today

big data

data-driven world

databases & database systems

when you see this, I want you to speak up!
[and you can always interrupt me]

Big Data

marketing term …

but …

science / government / business / personal data

exponentially growing data collections

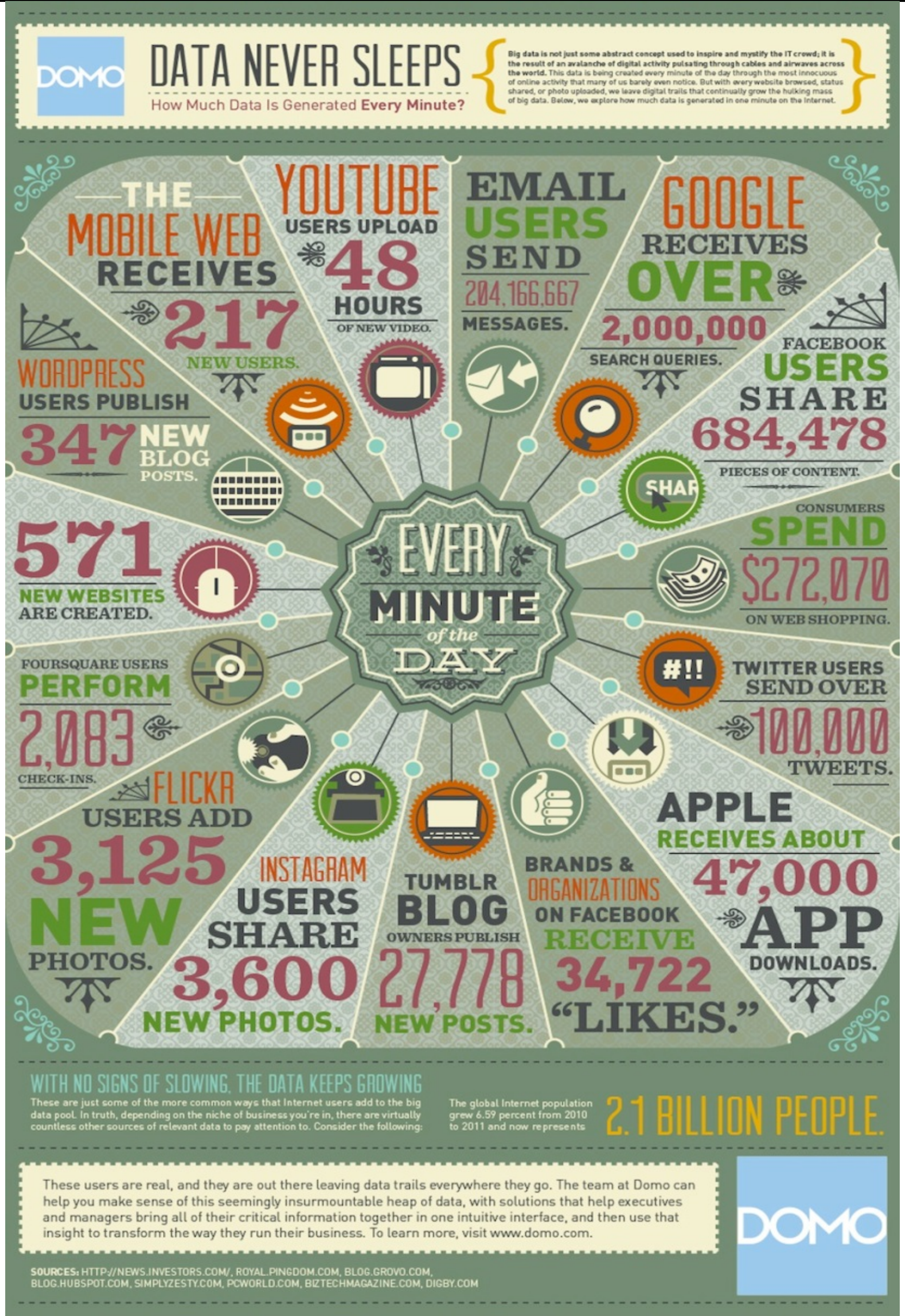
So, it is all good!

How big is "Big"?

Every day, we create 2.5 exabytes* of data — 90% of the data in the world today has been created in the last two years alone.

[Understanding Big Data, IBM]

*exabyte = 10^9 GB


DOMO
DATA NEVER SLEEPS
How Much Data Is Generated Every Minute?
THE MOBILE WEB RECEIVES 217 NEW USERS.
YOUTUBE USERS UPLOAD 48 HOURS OF NEW VIDEO.
EMAIL USERS SEND 204,166,667 MESSAGES.
GOOGLE RECEIVES OVER 2,000,000 SEARCH QUERIES.
FACEBOOK USERS SHARE 684,478 PIECES OF CONTENT.
SHARE
WORDPRESS USERS PUBLISH 347 NEW BLOG POSTS.
571 NEW WEBSITES ARE CREATED.
EVERY MINUTE of the DAY
CONSUMERS SPEND $272,070 ON WEB SHOPPING.
FOURSQUARE USERS PERFORM 2,083 CHECK-INS.
#!!
TWITTER USERS SEND OVER 100,000 TWEETS.
FLICKR USERS ADD 3,125 NEW PHOTOS.
INSTAGRAM USERS SHARE 3,600 NEW PHOTOS.
TUMBLR BLOG OWNERS PUBLISH 27,778 NEW POSTS.
BRANDS & ORGANIZATIONS ON FACEBOOK RECEIVE 34,722 "LIKES."
APPLE RECEIVES ABOUT 47,000 APP DOWNLOADS.
WITH NO SIGNS OF SLOWING, THE DATA KEEPS GROWING
2.1 BILLION PEOPLE.
DOMO

Big data is not just some abstract concept used to inspire and mystify the IT crowd; it is the result of an avalanche of digital activity pulsating through cables and airwaves across the world. This data is being created every minute of the day through the most innocuous of online activity that many of us barely even notice. But with every website browsed, status shared, or photo uploaded, we leave digital trails that continually grow the hulking mass of big data. Below, we explore how much data is generated in one minute on the Internet.

These are just some of the more common ways that Internet users add to the big data pool. In truth, depending on the niche of business you're in, there are virtually countless other sources of relevant data to pay attention to. Consider the following:

The global Internet population grew 6.59 percent from 2010 to 2011 and now represents 2.1 BILLION PEOPLE.

These users are real, and they are out there leaving data trails everywhere they go. The team at Domo can help you make sense of this seemingly insurmountable heap of data, with solutions that help executives and managers bring all of their critical information together in one intuitive interface, and then use that insight to transform the way they run their business. To learn more, visit www.domo.com.

SOURCES: HTTP://NEWS.INVESTORS.COM/, ROYAL.PINGDOM.COM, BLOG.GROVO.COM, BLOG.HUBSPOT.COM, SIMPLYZESTY.COM, PCWORLD.COM, BIZTECHMAGAZINE.COM, DIGBY.COM

Using Big Data

experimental physics (IceCube, CERN)
biology
neuroscience

data mining business datasets
machine learning for corporate and consumer

data analysis for fighting crime

… are only some examples

Data-Driven World

Big Data V’s

Volume

Velocity

Variety

Veracity

Information is transforming traditional business.

[“Data, data everywhere”, Economist]

CS460

we live in a ***data-driven*** world

CS460 is about the ***basics*** for
storing, ***using***, and ***managing*** data

your lecturer (that’s me!)

Manos Athanassoulis

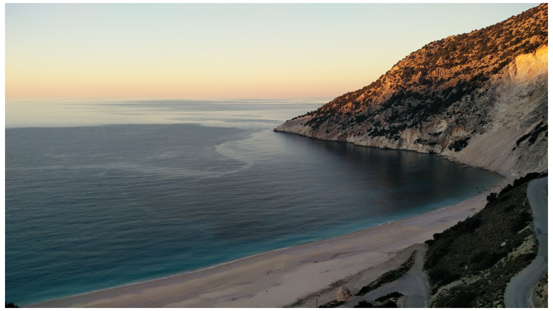
name in greek: Μάνος Αθανασούλης

grew up in Greece
enjoys playing basketball and the sea

BSc and MSc @ University of Athens, Greece
PhD @ EPFL, Switzerland
Research Intern @ IBM Research Watson, NY
Postdoc @ Harvard University

some awards:
Facebook Faculty Research Award
NSF CRII Research Award
Best of SIGMOD 2017, VLDB 2017

photo for VISA / conferences



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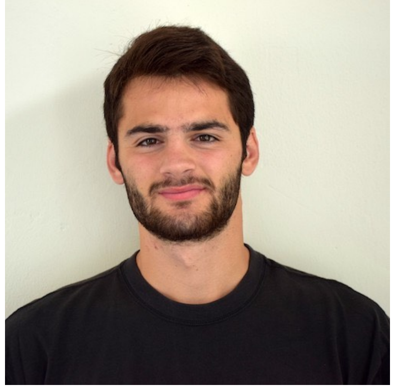
your awesome TAs



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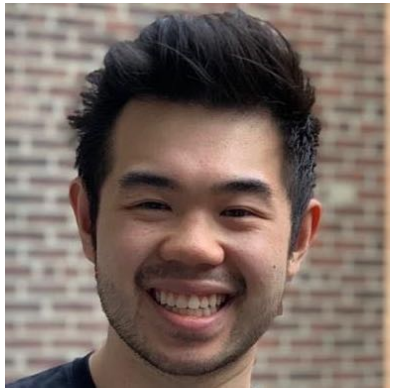


Andy Huynh
PhD student in DB
ndhuynh@bu.edu

Participation Administrativia

To enable remote participation we will be using Top Hat

The join code is: **193864.**

Lets’ try it out!

Data

to make data usable and manageable

we organize them in collections

Databases

a large, integrated, *structured* collection of data

intended to model some real-world enterprise

Examples: a university, a company, social media

University: students, professors, course

what is missing?

-- how to connect these?

-- enrollment, teaching

What about a company? What about social media?

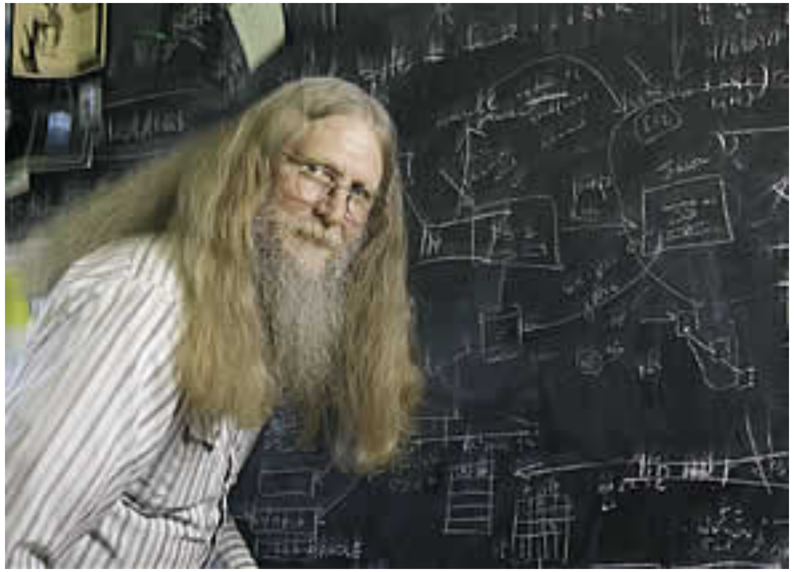
Database Systems

a.k.a. database management systems (DBMS)
a.k.a. data systems

Sophisticated pieces of software…

… which store, manage, organize, and facilitate access to my databases …

… so I can do things (and ask questions) that are otherwise hard or impossible



“relational databases are the foundation of western civilization”

Bruce Lindsay, IBM Research

ACM SIGMOD Edgar F. Codd Innovations award 2012

Ok but what really IS a database system?

Is the WWW a DBMS?

Is a File System a DBMS?

Is Facebook a DBMS?

Is the WWW a DBMS?

Not really!

Fairly sophisticated search available

web crawler *indexes* pages for fast search

.. but

data is unstructured and untyped

not well-defined “correct answer”

cannot update the data

freshness? consistency? fault tolerance?

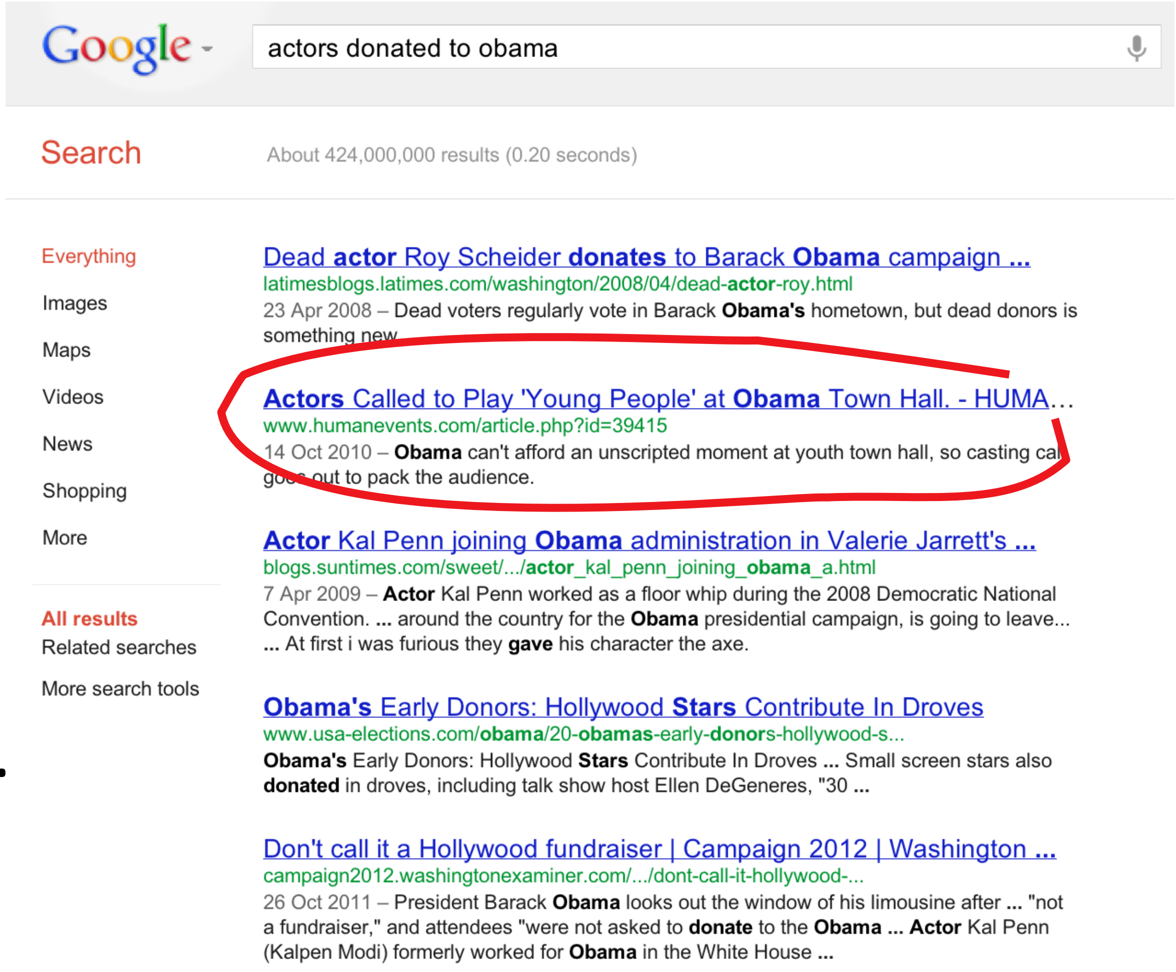
web sites **use** a *DBMS* to provide these functions

e.g., amazon.com (Oracle), facebook.com (MySQL and others)

"Search" vs. Query

What if you wanted to find out which actors donated to the first Barrack Obama's presidential campaign 12 years ago?

Try "actors donated to obama" in your favorite search engine.



actors donated to obama

About 424,000,000 results (0.20 seconds)

Dead actor Roy Scheider donates to Barack Obama campaign ...
latimesblogs.latimes.com/washington/2008/04/dead-**actor**-roy.html
23 Apr 2008 – Dead voters regularly vote in Barack **Obama's** hometown, but dead donors is something new.

Actors Called to Play 'Young People' at Obama Town Hall. - HUMA...
www.humanevents.com/article.php?id=39415
14 Oct 2010 – **Obama** can't afford an unscripted moment at youth town hall, so casting cal goes out to pack the audience.

Actor Kal Penn joining Obama administration in Valerie Jarrett's ...
blogs.suntimes.com/sweet/.../**actor**_kal_penn_joining_**obama**_a.html
7 Apr 2009 – **Actor** Kal Penn worked as a floor whip during the 2008 Democratic National Convention. **...** around the country for the **Obama** presidential campaign, is going to leave... **...** At first i was furious they **gave** his character the axe.

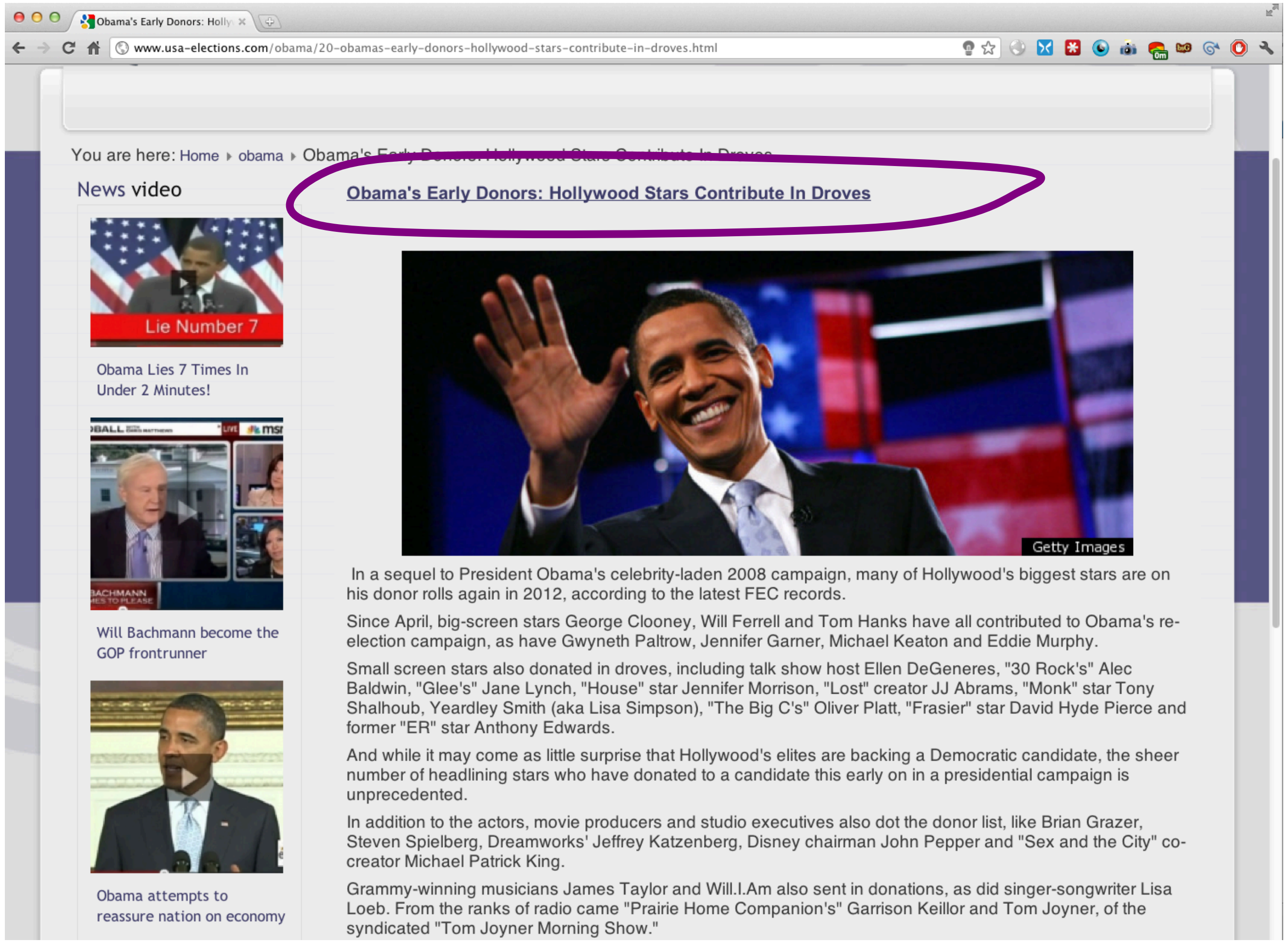
Obama's Early Donors: Hollywood Stars Contribute In Droves
www.usa-elections.com/**obama**/20-**obamas**-early-**donors**-hollywood-s...
Obama's Early Donors: Hollywood **Stars** Contribute In Droves **...** Small screen stars also **donated** in droves, including talk show host Ellen DeGeneres, "30 **...**

Don't call it a Hollywood fundraiser | Campaign 2012 | Washington ...
campaign2012.washingtonexaminer.com/.../dont-call-it-hollywood-...
26 Oct 2011 – President Barack **Obama** looks out the window of his limousine after **...** "not a fundraiser," and attendees "were not asked to **donate** to the **Obama** **...** **Actor** Kal Penn (Kalpen Modi) formerly worked for **Obama** in the White House **...**

“Search” vs. Query

“Search” can return only what’s been “stored”

E.g., best match at Google:


Obama's Early Donors: Holly
www.usa-elections.com/obama/20-obamas-early-donors-hollywood-stars-contribute-in-droves.html
Lie Number 7
Getty Images

You are here: Home ▸ obama ▸ Obama's Early Donors: Hollywood Stars Contribute In Droves

News video

Obama Lies 7 Times In Under 2 Minutes!

Will Bachmann become the GOP frontrunner

Obama attempts to reassure nation on economy

Obama's Early Donors: Hollywood Stars Contribute In Droves

In a sequel to President Obama's celebrity-laden 2008 campaign, many of Hollywood's biggest stars are on his donor rolls again in 2012, according to the latest FEC records.

Since April, big-screen stars George Clooney, Will Ferrell and Tom Hanks have all contributed to Obama's re-election campaign, as have Gwyneth Paltrow, Jennifer Garner, Michael Keaton and Eddie Murphy.

Small screen stars also donated in droves, including talk show host Ellen DeGeneres, "30 Rock's" Alec Baldwin, "Glee's" Jane Lynch, "House" star Jennifer Morrison, "Lost" creator JJ Abrams, "Monk" star Tony Shalhoub, Yeardley Smith (aka Lisa Simpson), "The Big C's" Oliver Platt, "Frasier" star David Hyde Pierce and former "ER" star Anthony Edwards.

And while it may come as little surprise that Hollywood's elites are backing a Democratic candidate, the sheer number of headlining stars who have donated to a candidate this early on in a presidential campaign is unprecedented.

In addition to the actors, movie producers and studio executives also dot the donor list, like Brian Grazer, Steven Spielberg, Dreamworks' Jeffrey Katzenberg, Disney chairman John Pepper and "Sex and the City" co-creator Michael Patrick King.

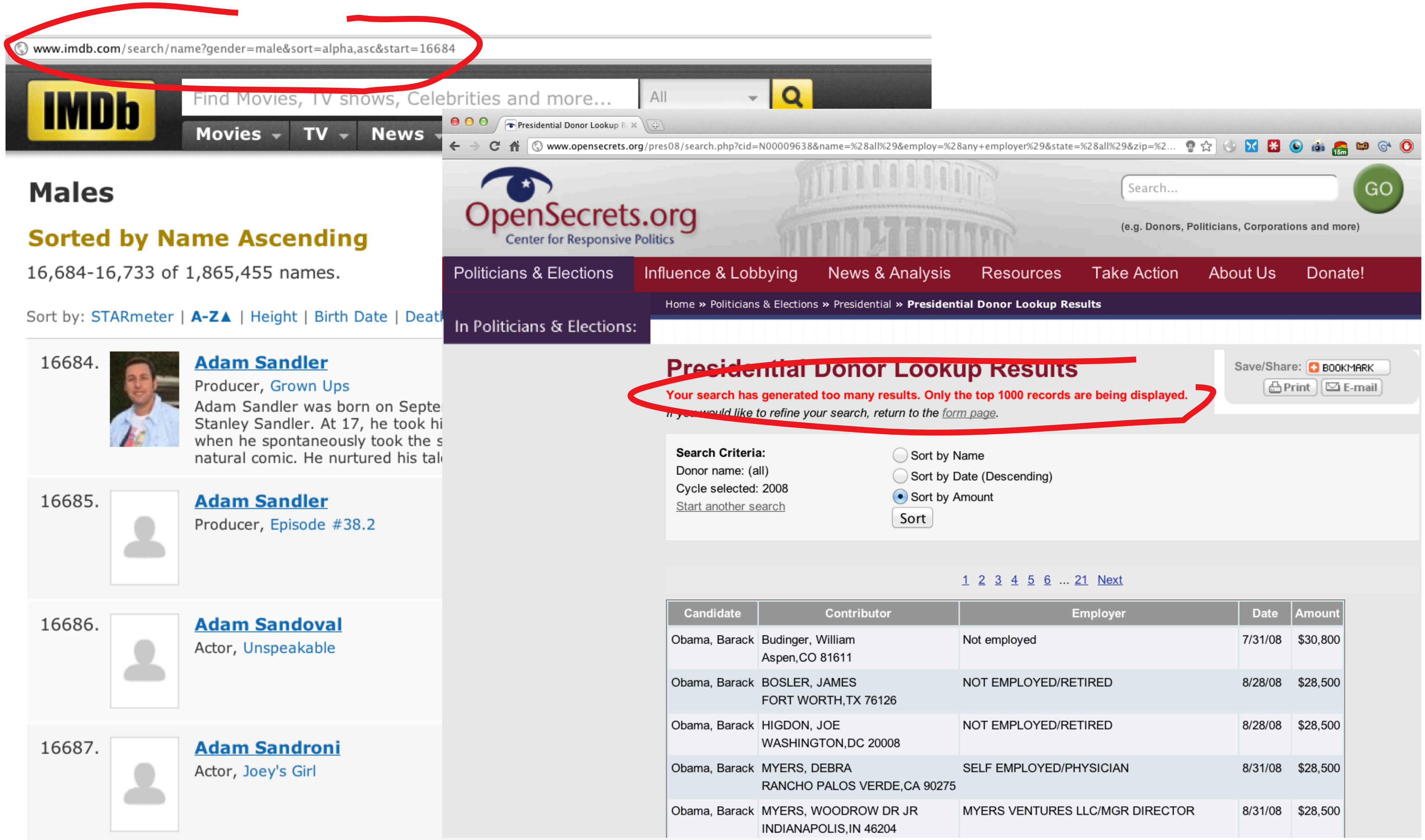
Grammy-winning musicians James Taylor and Will.I.Am also sent in donations, as did singer-songwriter Lisa Loeb. From the ranks of radio came "Prairie Home Companion's" Garrison Keillor and Tom Joyner, of the syndicated "Tom Joyner Morning Show."

A “Database Query” Approach

where can we find
data for ”all actors”?

where can we find
data for ”all donations”?

A “Database Query” Approach



www.imdb.com/search/name?gender=male&sort=alpha,asc&start=16684

Males

Sorted by Name Ascending

16,684-16,733 of 1,865,455 names.

Sort by: STARmeter | A-Z▲ | Height | Birth Date | Deat

16684. Adam Sandler
Producer, Grown Ups
Adam Sandler was born on Septe
Stanley Sandler. At 17, he took hi
when he spontaneously took the s
natural comic. He nurtured his tal

16685. Adam Sandler
Producer, Episode #38.2

16686. Adam Sandoval
Actor, Unspeakable

16687. Adam Sandroni
Actor, Joey's Girl

www.opensecrets.org/pres08/search.php?cid=N00009638&name=%28all%29&employ=%28any+employer%29&state=%28all%29&zip=%2...

Presidential Donor Lookup R
OpenSecrets.org
Center for Responsive Politics
Search...
GO
(e.g. Donors, Politicians, Corporations and more)
Politicians & Elections
Influence & Lobbying
News & Analysis
Resources
Take Action
About Us
Donate!
Home » Politicians & Elections » Presidential » Presidential Donor Lookup Results
In Politicians & Elections:
Save/Share: BOOKMARK
Print
E-mail

Presidential Donor Lookup Results

Your search has generated too many results. Only the top 1000 records are being displayed.

If you would like to refine your search, return to the form page.

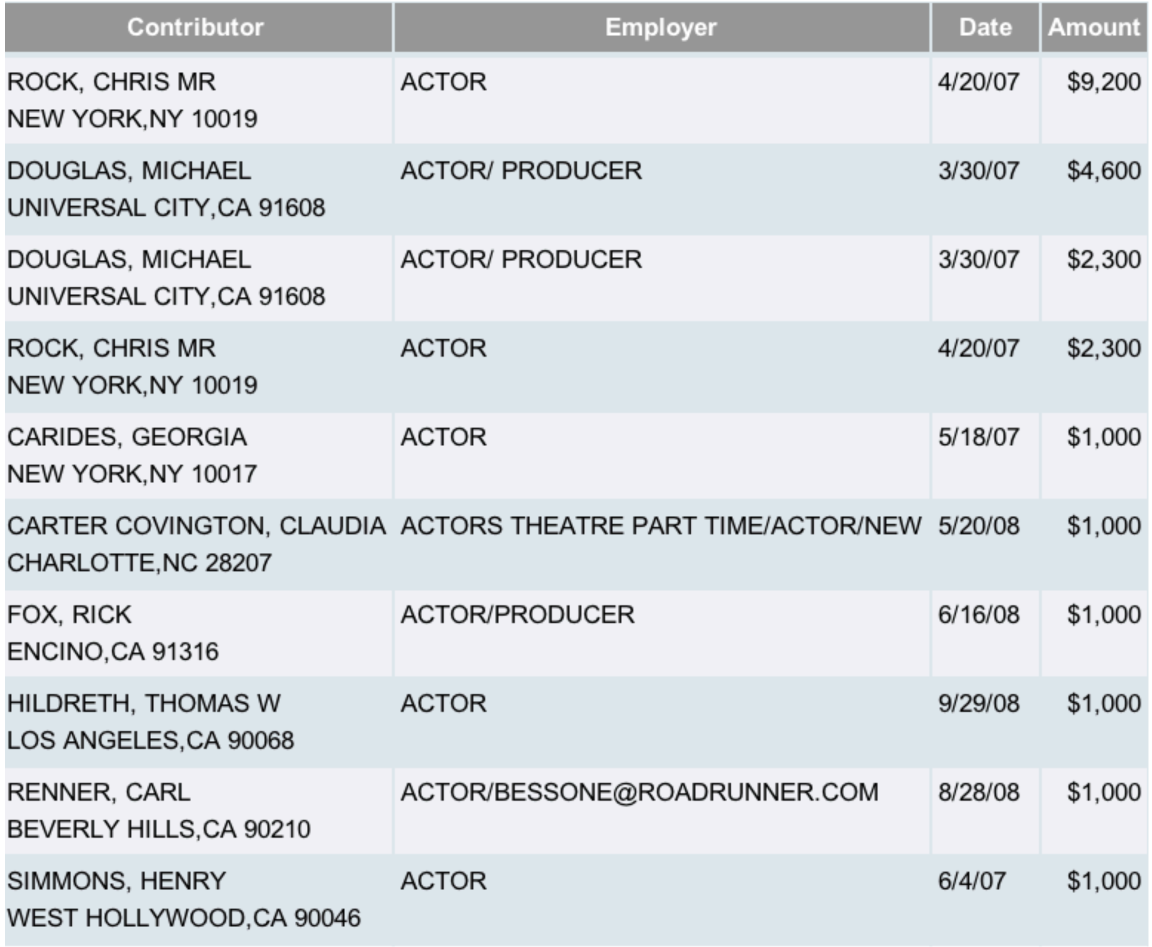
Search Criteria:
Donor name: (all)
Cycle selected: 2008
Start another search

○ Sort by Name
○ Sort by Date (Descending)
● Sort by Amount
Sort

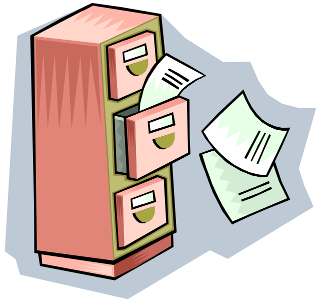
1 2 3 4 5 6 ... 21 Next

Candidate	Contributor	Employer	Date	Amount
Obama, Barack	Budinger, William Aspen,CO 81611	Not employed	7/31/08	$30,800
Obama, Barack	BOSLER, JAMES FORT WORTH,TX 76126	NOT EMPLOYED/RETIRED	8/28/08	$28,500
Obama, Barack	HIGDON, JOE WASHINGTON,DC 20008	NOT EMPLOYED/RETIRED	8/28/08	$28,500
Obama, Barack	MYERS, DEBRA RANCHO PALOS VERDE,CA 90275	SELF EMPLOYED/PHYSICIAN	8/31/08	$28,500
Obama, Barack	MYERS, WOODROW DR JR INDIANAPOLIS,IN 46204	MYERS VENTURES LLC/MGR DIRECTOR	8/31/08	$28,500

“IMDB Actors” JOIN “OpenSecrets”



Contributor	Employer	Date	Amount
ROCK, CHRIS MR NEW YORK,NY 10019	ACTOR	4/20/07	$9,200
DOUGLAS, MICHAEL UNIVERSAL CITY,CA 91608	ACTOR/ PRODUCER	3/30/07	$4,600
DOUGLAS, MICHAEL UNIVERSAL CITY,CA 91608	ACTOR/ PRODUCER	3/30/07	$2,300
ROCK, CHRIS MR NEW YORK,NY 10019	ACTOR	4/20/07	$2,300
CARIDES, GEORGIA NEW YORK,NY 10017	ACTOR	5/18/07	$1,000
CARTER COVINGTON, CLAUDIA CHARLOTTE,NC 28207	ACTORS THEATRE PART TIME/ACTOR/NEW	5/20/08	$1,000
FOX, RICK ENCINO,CA 91316	ACTOR/PRODUCER	6/16/08	$1,000
HILDRETH, THOMAS W LOS ANGELES,CA 90068	ACTOR	9/29/08	$1,000
RENNER, CARL BEVERLY HILLS,CA 90210	ACTOR/BESSONE@ROADRUNNER.COM	8/28/08	$1,000
SIMMONS, HENRY WEST HOLLYWOOD,CA 90046	ACTOR	6/4/07	$1,000

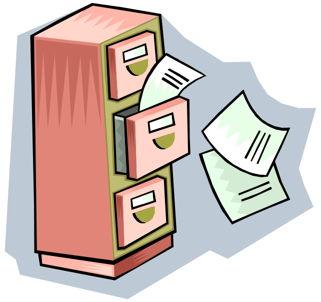


Is a File System a DBMS?

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) ???**



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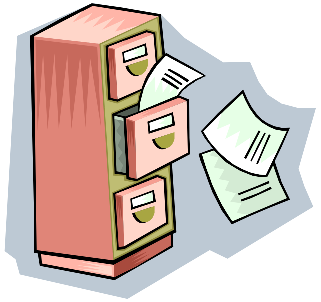
Thought Experiment 2:

- You’re updating a file.
- The power goes out.
- Which of your changes survive?

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



Is a File System a DBMS?

Not really!

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Is Facebook a DBMS?

Is the data structured & typed?

Does it offer well-defined queries?

Not really!

Does it offer properties like “durability” and “consistency”?

Facebook is a data-driven company that uses several database systems (>10) for different use-cases (internal or external).

Why take this class?

computation to *information*

corporate, personal (web), science (big data)

database systems *everywhere*

data-driven world, data companies

DBMS: much of CS as a practical discipline

languages, theory, OS, logic, architecture, HW

CS460 in a nutshell

model
data representation model

query
query languages – ad hoc queries

access (concurrently multiple reads/writes)
ensure *transactional* semantics

store (reliably)
maintain *consistency/semantics* in *failures*

A “free taste” of the class

data modeling

query languages

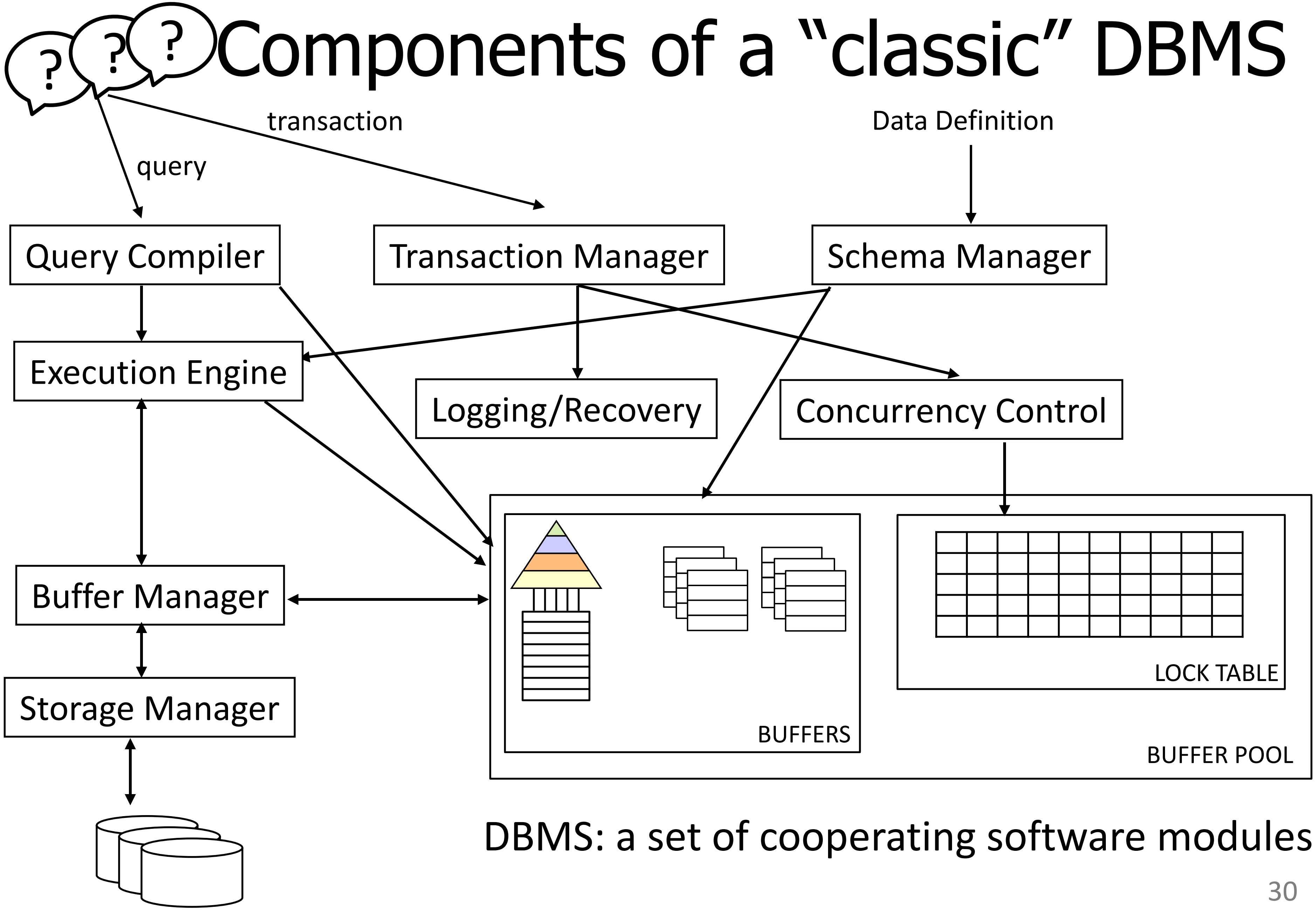
concurrent, fault-tolerant data management

DBMS architecture

Coming in next class

Discussion on *database systems* ***designs***

Components of a “classic” DBMS



DBMS: a set of cooperating software modules

Describing Data: Data Models

data model : a collection of concepts describing data

relational model is the most widely used model today

key concepts

relation : basically a table with rows and columns

schema : describes the columns (or fields) of each table

Schema of “University” Database

Students

***sid**: string, **name**: string, **login**: string, **age**: integer, **gpa**: real*

Courses

***cid**: string, **cname**: string, **credits**: integer*

Enrolled

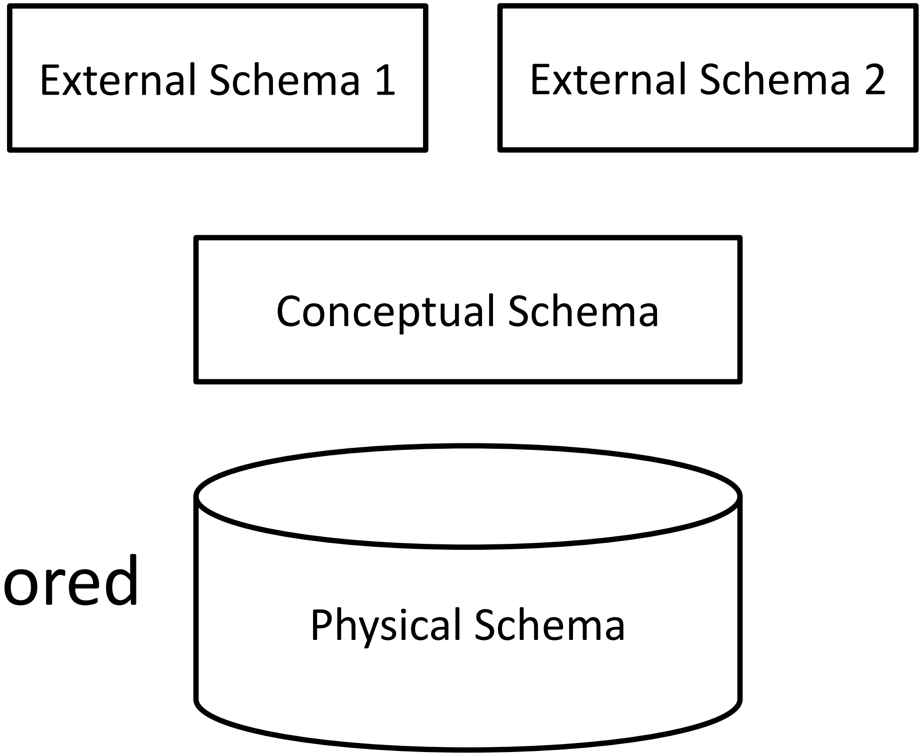
***sid**: string, **cid**: string, **grade**: string*

Levels of Abstraction

what the users *see*

what is the *data model*

how the data is *physically* stored
e.g., files, indexes



External Schema 1

External Schema 2

Conceptual Schema

Physical Schema

Schemas of “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 in heap files
indexes for sid/cid

Schemas of "University" Database

External Schema

a "view" of data that can be derived from the existing data

example: Course Info

*Course_Info (**cid**: string, **enrollment**:integer)*

Data Independence

Abstraction offers “application independence”

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?

Applications can treat DBMS as black boxes!

Queries

”Bring me all students with gpa more than 3.0”

“SELECT * FROM Students WHERE gpa>3.0”

SQL – a powerful *declarative* query language

treats DBMS as a black box

What if we have multiples accesses?

Concurrency Control

multiple users/apps

Challenges

how frequent access to slow medium

how to keep CPU busy

how to avoid *short jobs* waiting behind *long ones*

e.g., ATM withdrawal while summing all *balances*

interleaving actions of *different* programs

Concurrency Control

Problems with *interleaving* actions of diff. programs

Bill

Move 100 from savings to checking

Alice

Bad interleaving:

Savings –= 100

Print balances

Checking += 100

Printout is missing 100$!

Concurrency Control

Problems with *interleaving* actions of diff. programs

Bill

Move 100 from savings to checking

Alice

What is a correct interleaving?

Savings –= 100

Checking += 100

Print balances

How to achieve this interleaving?

Scheduling Transactions

Transactions: atomic sequences of **R**eads & **W**rites

T_{Bill}={$R1_{Savings}$, $R1_{Checking}$, $W1_{Savings}$, $W1_{Checking}$}
T_{Alice}={$R2_{Savings}$, $R2_{Checking}$}

How to avoid previous problems?

Scheduling Transactions

All interleaved executions equivalent to a *serial*

All actions of a transaction executed *as a whole*

Time

$R1_{Savings}$, $R1_{Checking}$, $W1_{Savings}$, $W1_{Checking}$, $R2_{Savings}$, $R2_{Checking}$

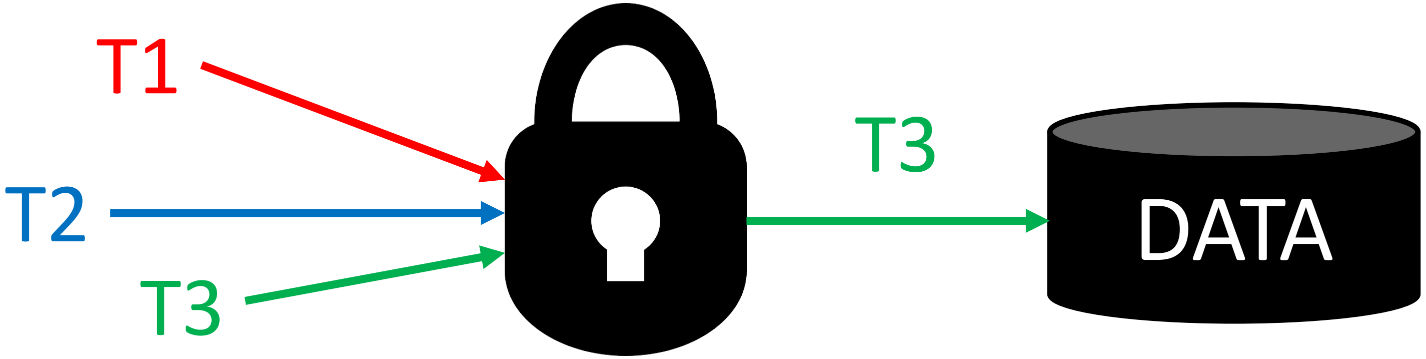
$R2_{Savings}$, $R2_{Checking}$, $R1_{Savings}$, $R1_{Checking}$, $W1_{Savings}$, $W1_{Checking}$

~~$R1_{Savings}$, $R1_{Checking}$, $W1_{Savings}$, $R2_{Savings}$, $R2_{Checking}$, $W1_{Checking}$~~

$R1_{Savings}$, $R1_{Checking}$, $R2_{Savings}$, $R2_{Checking}$, $W1_{Savings}$, $W1_{Checking}$

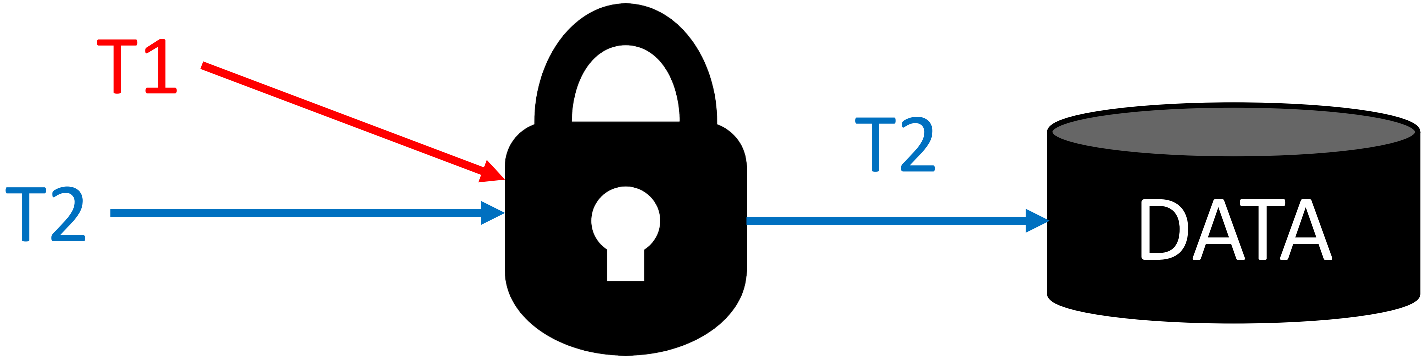
How to achieve one of these?

Locking



before an object is accessed a lock is requested

Locking



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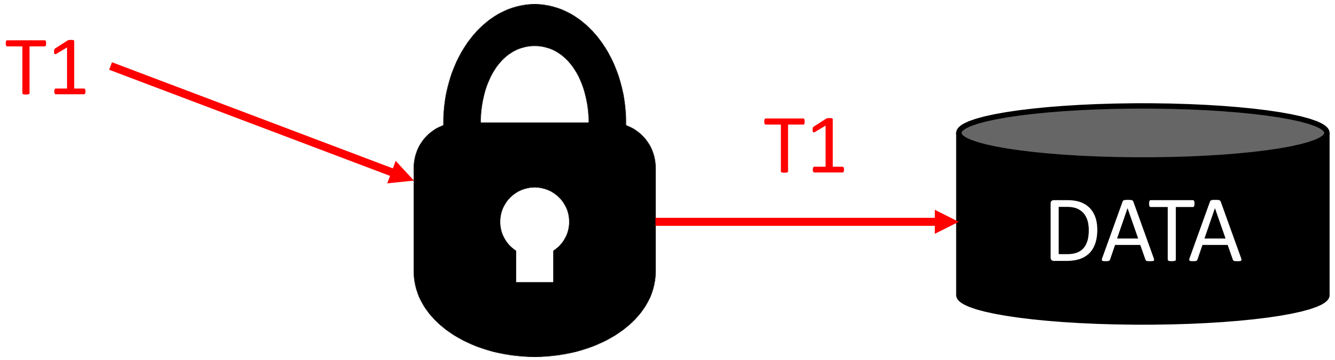
Locking



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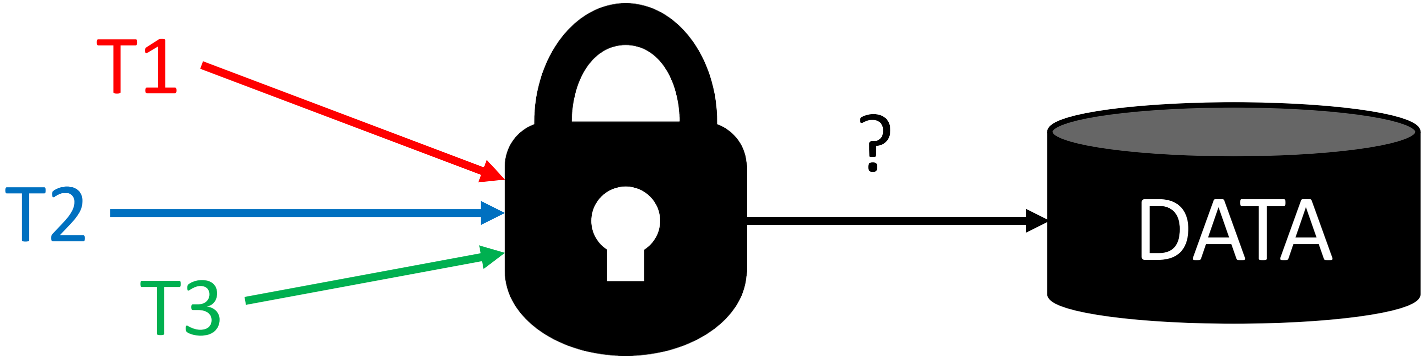
Locking



locks are held until the end of the transaction

[this is only one way to do this, called “strict two-phase locking”]

Locking

T_1={$R1_{Savings}$, $R1_{Checking}$, $W1_{Savings}$, $W1_{Checking}$}
T_2={$R2_{Savings}$, $R2_{Checking}$}

Both should lock *Savings* and *Checking*

What happens:

if T1 locks Savings & Checking ?

T2 has to wait

if T1 locks Savings & T2 locks Checking ?

we have a deadlock

How to solve deadlocks?

we need a mechanism to *undo*

also when a transaction is *incomplete*

e.g., due to a crash

what can be an undo mechanism?

log every action before it is applied!

Transactional Semantics

Transaction: one execution of a user program

multiple executions → multiple transactions

Every transaction:

Logging → ***A**tomic*

***C**onsistent*

***I**solated*

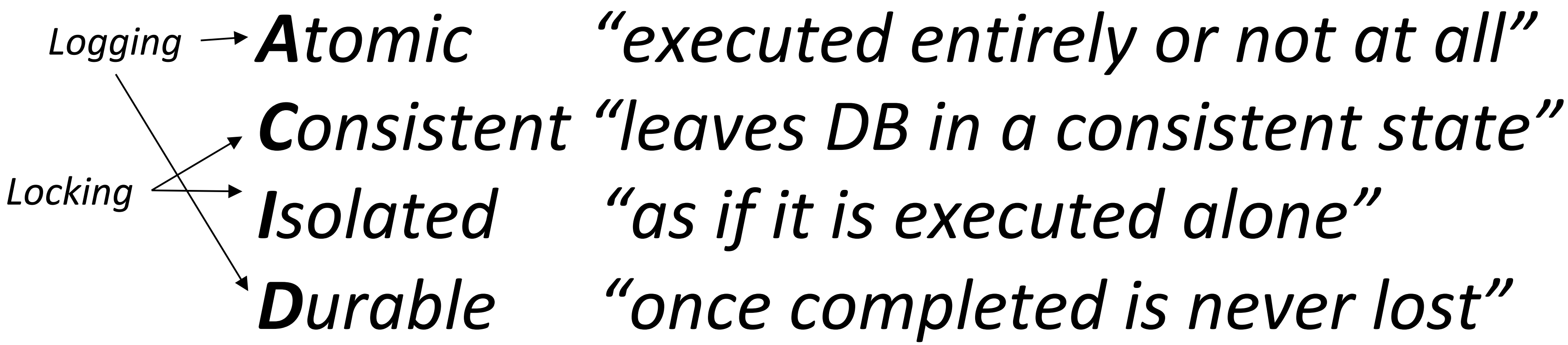
***D**urable*

Transactional Semantics

Transaction: one execution of a user program

multiple executions → multiple transactions

Every transaction:



***A**tomic* *“executed entirely or not at all”*

***C**onsistent* *“leaves DB in a consistent state”*

***I**solated* *“as if it is executed alone”*

***D**urable* *“once completed is never lost”*

Who else needs transactions?

lots of data

lots of users

frequent updates

background game analytics

Scaling games to epic proportions,

by W. White, A. Demers, C. Koch, J. Gehrke and R. Rajagopalan

ACM SIGMOD International Conference on Management of Data, 2007

Only “classic” DBMS?

No, there is much more!

NoSQL & Key-Value Stores: No transactions, focus on queries

Graph Stores

Querying raw data without loading/integrating costs

Database queries in large datacenters

New hardware and storage devices

… many exciting open problems!

https://bu-disc.github.io/CS460/

Next time in …

CS 460: Introduction to Database Systems

Database Systems Architectures

Class administrativia

Class project administrativia

https://bu-disc.github.io/CS460/

Additional Accommodations

If you require additional accommodations please contact the Disability & Access Services office at aslods@bu.edu or 617-353-3658 to make an appointment with a DAS representative to determine which are the appropriate accommodations for your case.

Please be aware that accommodations cannot be enacted retroactively, making timeliness a critical aspect for their provision.

You can optionally choose to disclose this information to the instructor.