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CS 591: Data Systems Architectures

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http://manos.athanassoulis.net/classes/CS591

Today

big data

data-driven world

data systems *which are the main drivers?*

why do we need new designs?

CS591 goals & logistics

I want you to speak up!
[and you can always interrupt me]

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CS591 philosophy

cutting-edge research

question everything (to understand it better!)

interactive & collaborative

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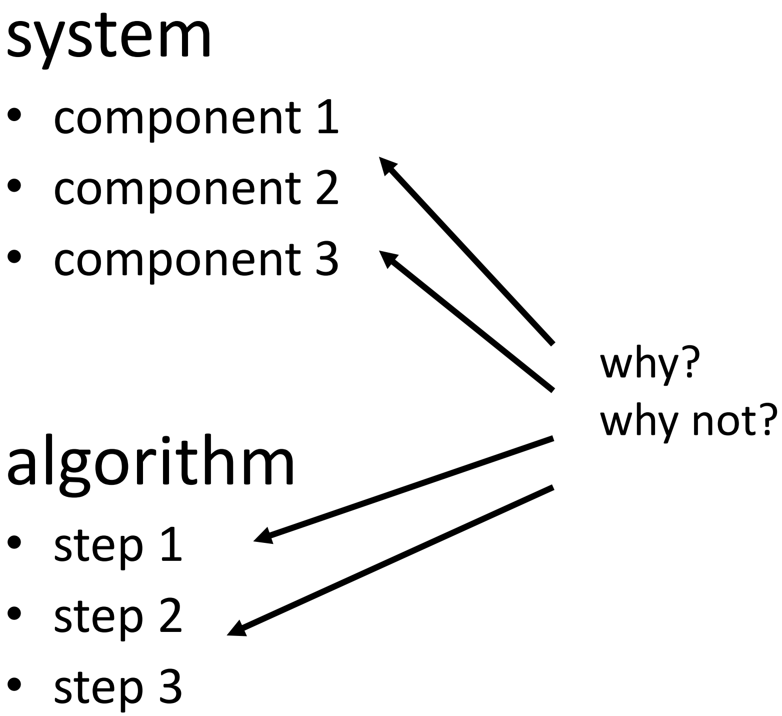
Understanding a design/system/algorithm …



system

- component 1
- component 2
- component 3

why?
why not?

algorithm

- step 1
- step 2
- step 3

understanding all steps and all decisions
helps us see the ***big picture***
and do **good research**!

(otherwise we make ad hoc choices!)

Ask Questions!

… and answer my questions!

our **main goal** is to have **interesting discussions** that will help to gradually understand what the material discusses

(it's ok if not everything is clear, as long as you have questions!)

Read papers

every class **1 paper to discuss** in detail – **presented by a student** (background papers to provide more details)

read all of them!

write reviews (every class 1 review, you can skip 3 reviews)

Presentations

for every class, **one student will be responsible for presenting** the paper (discussing all main points of a long review – see next slide)

during the presentation **anyone can ask questions** (including me!) and each question is **addressed to all** (including me!)

the presenting student will **prepare <u>slides</u> and <u>questions</u>**

Reviews

5 long reviews and the **rest short reviews**

short review (up to half page)
Par. 1: what is the problem & why it is important
Par. 2: what is the main idea of the solution

long review (up to one page)
what is the problem & why it is important?
why is it hard & why older approaches are not enough?
what is key idea and why it works?
what is missing and how can we improve this idea?
does the paper supports its claims?
possible next steps of the work presented in the paper?

remember, this will helps us do **good research**!

systems project

implementation-heavy C/C++ project

group of 1-2

research project

group of 3-4

pick a subject (list will be available)

design & analysis

experimentation

Project theme: NoSQL key-value stores

… are everywhere

work on a ***state-of-the-art*** design

Project: open questions

tuning based on workload

quickly delete and free-up resources

exploit ***data being sorted***

data ***partitioning*** for complex workloads

more on the website (soon)

A good project

GOOD JOB!
WELL DONE
GOOD JOB!

has a clear plan by mid-way proposal (10% - early March)

evaluation at the end of the semester:

(i) present the key ideas of the implementation/new approach

(ii) present a set of experiments supporting your claims

come to OH!

(more details for the projects in Class 4 next week)

The ultimate reward!

ACM SIGMOD Undergrad Research Competition

The **top conference in data management**

ACM Special Interest Group in Data Management (SIGMOD)

receives submissions of ***student research***

top 10-15 **are invited to present their work** at the conference

top-3 projects get an award and **invitation to present at the ACM** level (all of computer science)

Class Goal

understand the internals of

<u>data systems for data science</u>

tune data systems through **adaptation** and **automation**

get acquainted with research in the area

Can I take this class?

background

programming

data structures

algorithms

comp. architecture

pre-req

CS460/660 & CS210 or CS350

contact Manos if not sure

how to be sure?

if familiar with most, then maybe!

if familiar with **none**, then no!

Next classes

Class 1-2
logistics, big data, data systems, trends and outlook

Class 3
more basics on data systems, systems classification, graph, cloud

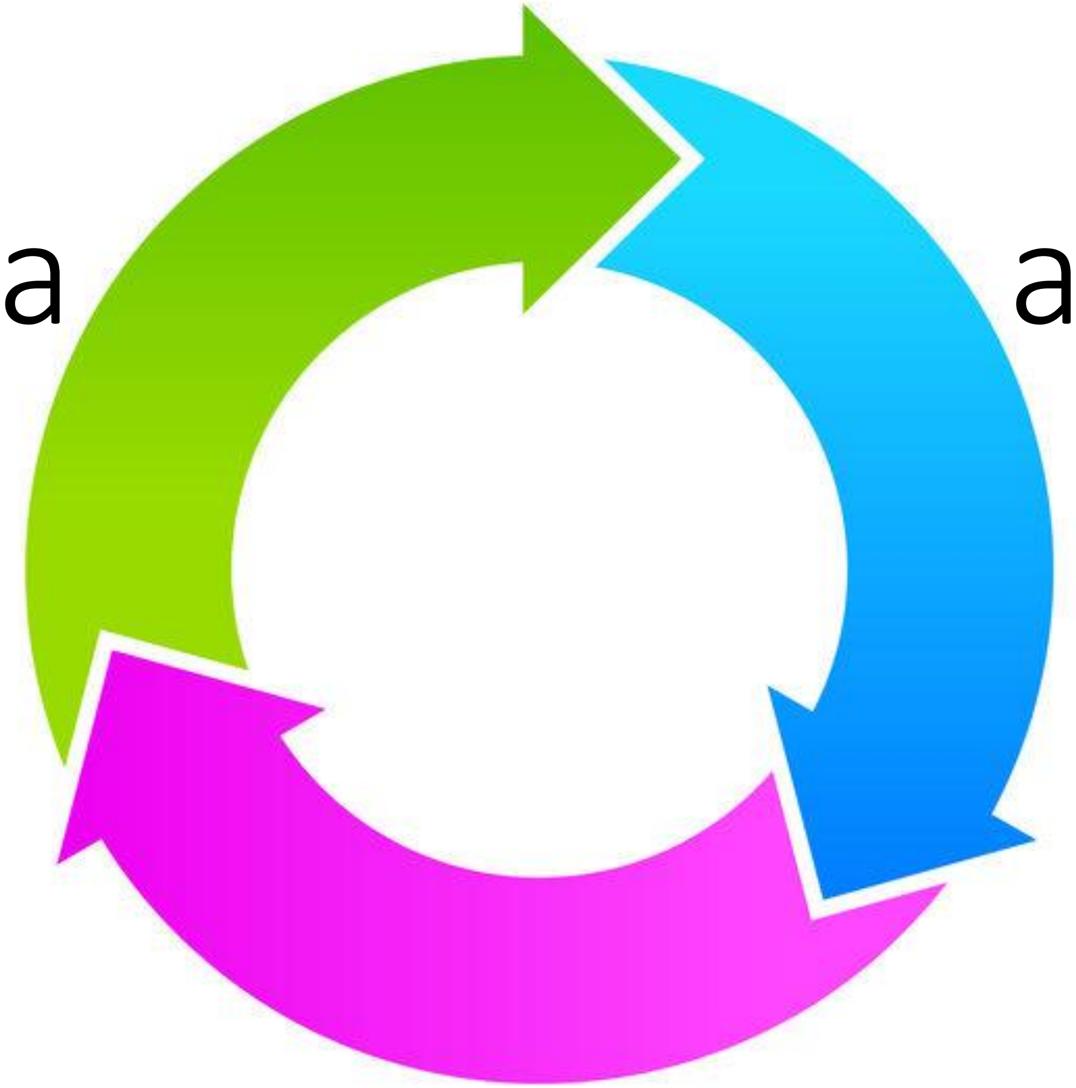
Class 4
intro to class project

Class 5 and beyond
present and **discuss** research papers

big data?

who doesn't have a lot of data?

what is new?



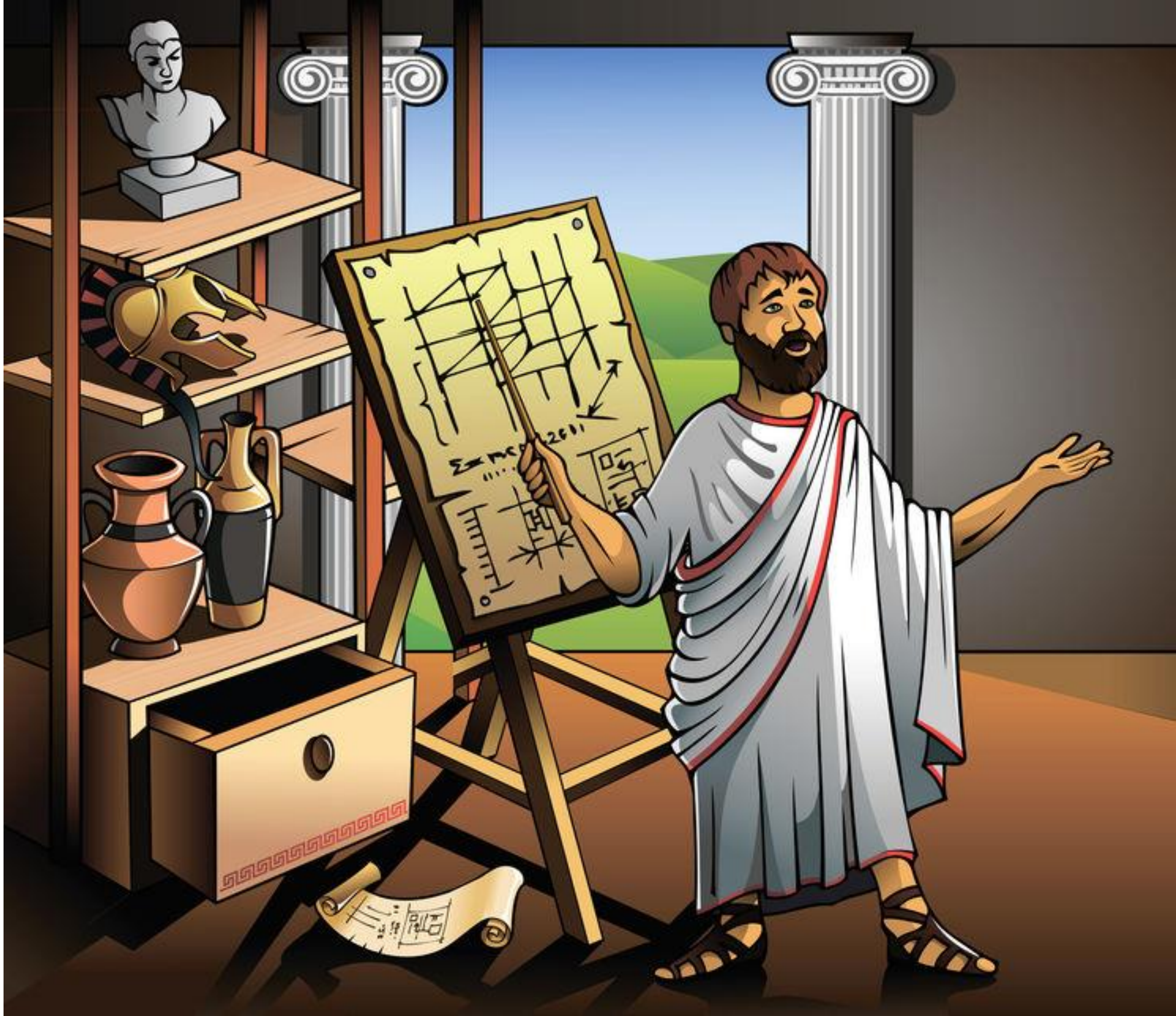
data

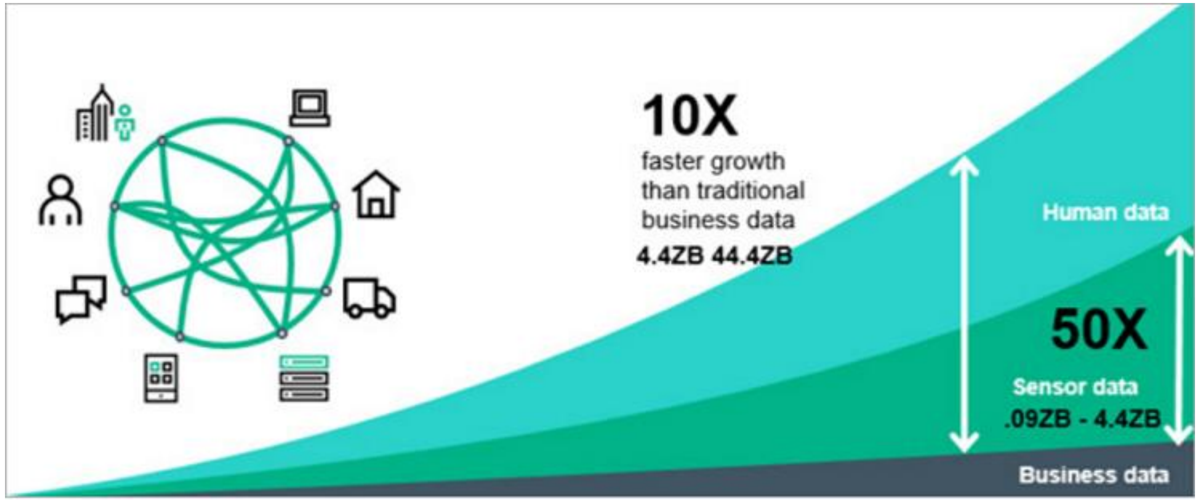
analysis

knowledge

is data analysis new?

what is *really* new?

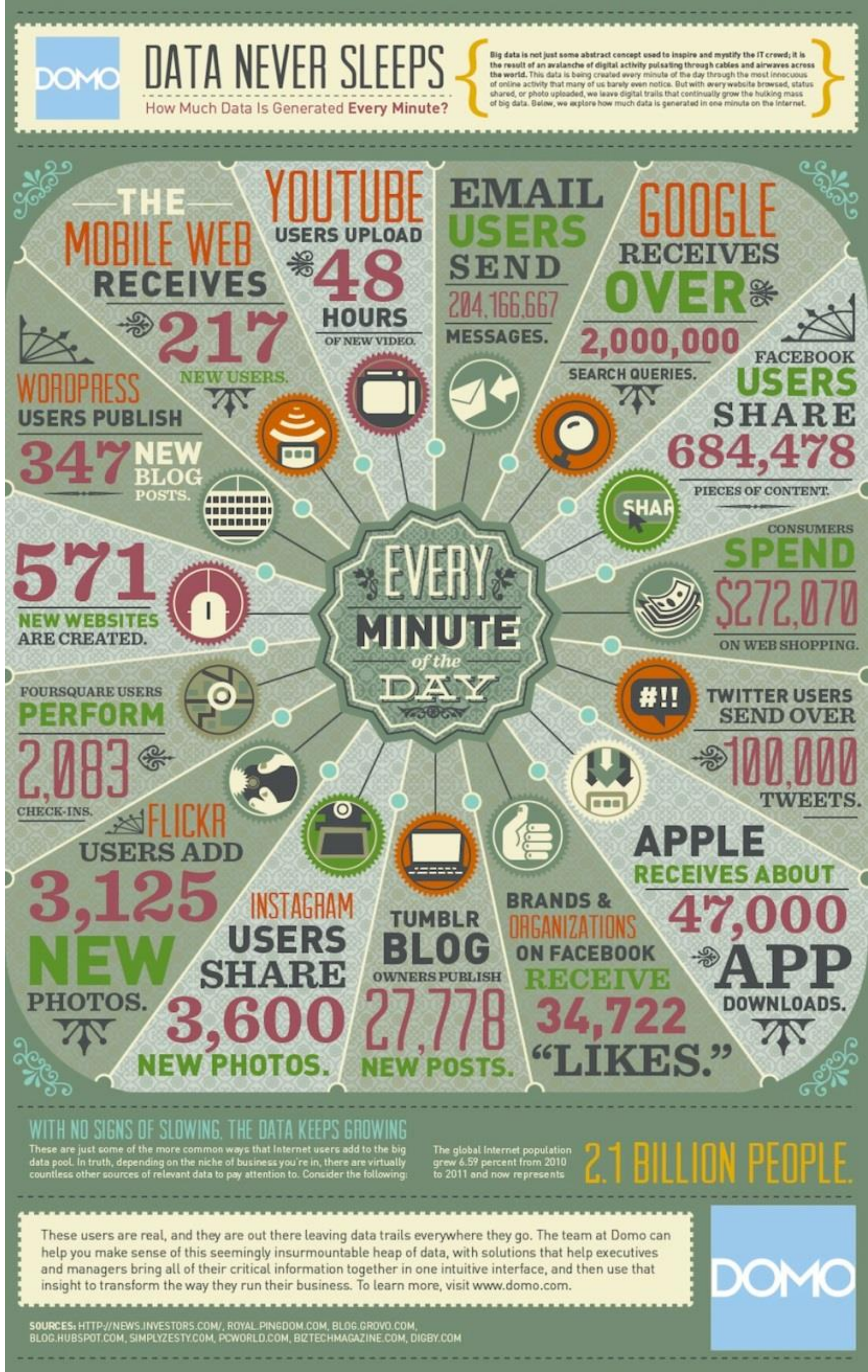




Every day, we create 2.5 exabytes* of data — 90% of the data in the world today has been created in the last two years alone.

[Understanding Big Data, IBM]

*exabyte = 10^9 GB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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.
WORDPRESS USERS PUBLISH 347 NEW BLOG POSTS.
571 NEW WEBSITES ARE CREATED.
CONSUMERS SPEND $272,070 ON WEB SHOPPING.
EVERY MINUTE of the DAY
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.
SHAR
#!!
WITH NO SIGNS OF SLOWING, THE DATA KEEPS GROWING
2.1 BILLION PEOPLE.
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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

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

data management skills needed

100s of entries	**pen & paper**
10^3-10^6 of entries	**unix tools and excel**
10^9 of entries	**custom solutions, programming**
10^{12+} of entries	**data systems**

size (volume)

rate (velocity)

sources (variety)

big data

(it's not only about size)

all of the above plus …

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our ability to collect ***machine-generated*** data

scientific experiments

sensors

social

monitoring

micro-payments

Internet-of-Things

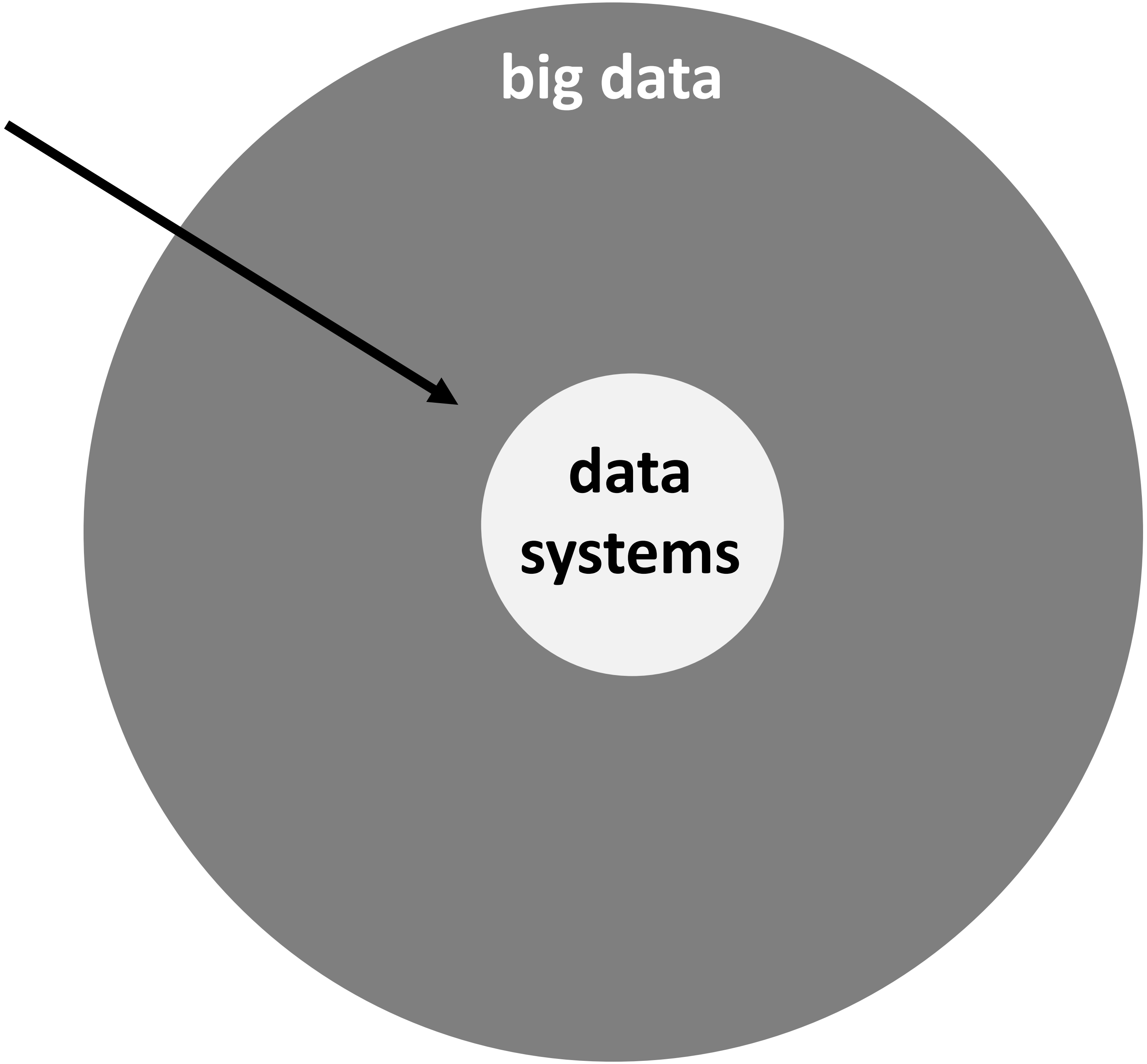
cloud

data analysis

know what we are looking for

data exploration

not sure what we are looking for



data systems are
in the middle of this!

what is a **data system**?

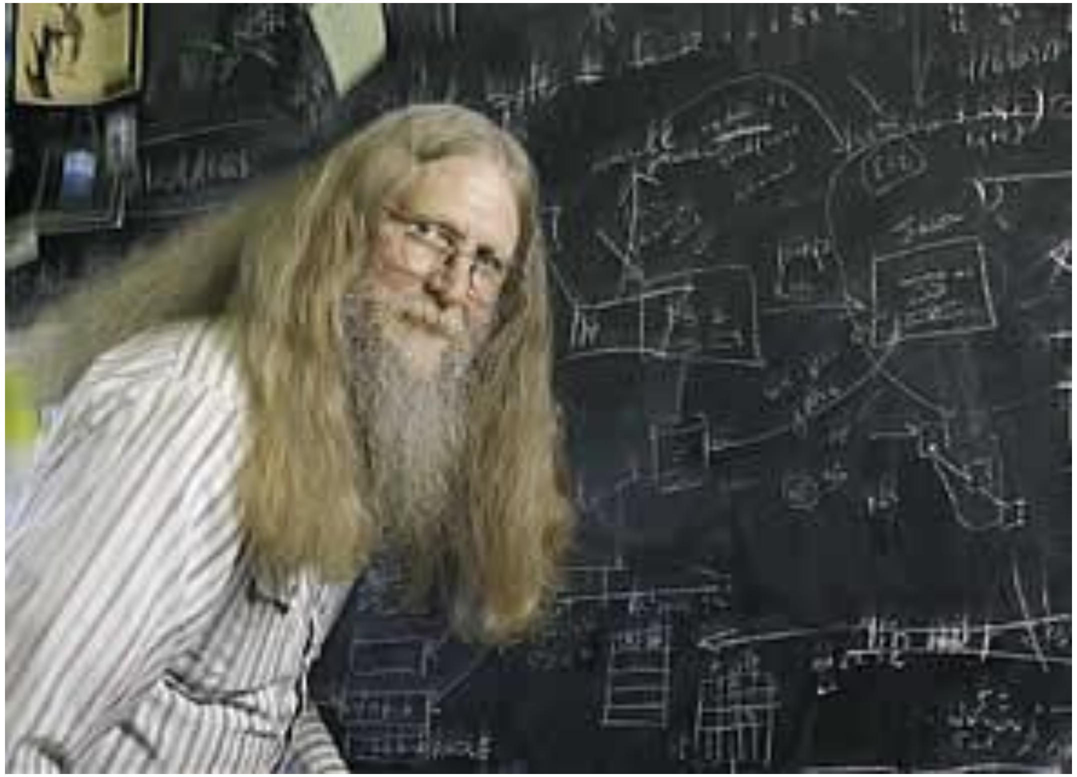
a **data system** is a large software system

(a collection of algorithms and data structures)

that **stores data**, and provides the **interface** to

update and **access** them **efficiently**

the end goal is to make **data analysis** easy



“relational databases are the foundation of western civilization”

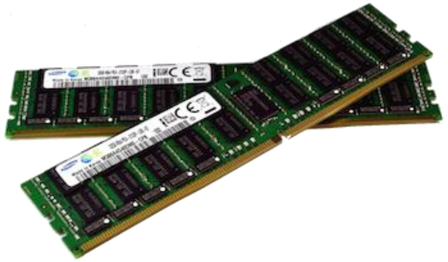
Bruce Lindsay, IBM Research

ACM SIGMOD Edgar F. Codd Innovations award 2012

data systems are everywhere

growing need for tailored systems

future



Why?

new applications

new hardware

more data

The big success of 5 decades of research

a declarative interface!

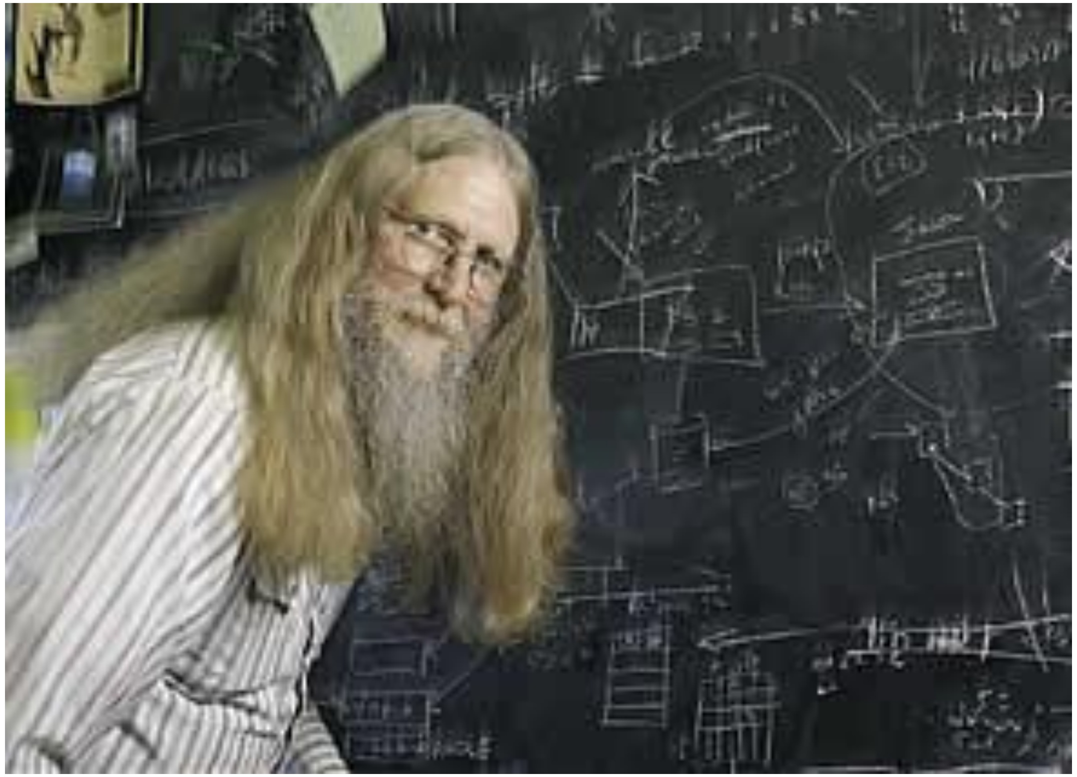
“ask and thou shall receive”

ask ***what*** you want

data system

system decides ***how***
to store & access

is this good? why?

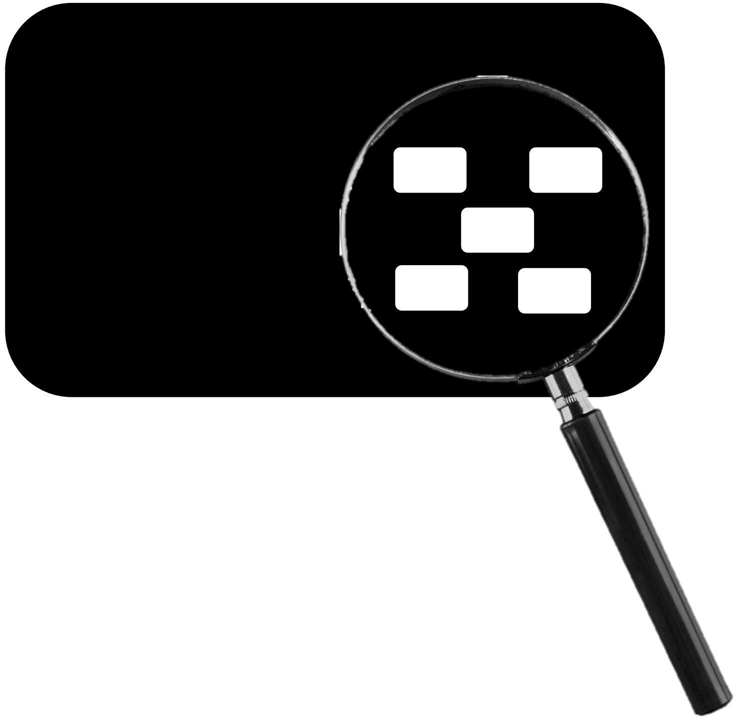


“three things are important in the database world: ***performance, performance,*** *and* ***performance****”*

Bruce Lindsay, IBM Research

ACM SIGMOD Edgar F. Codd Innovations award 2012

CS591: data systems **kernel** under the looking glass



this is where we will spend our time!

system architecture (row/column/hybrid)

indexing

relational/graph/key-value

scale-up/scale-out

goal: learn to design and implement a db kernel

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how to design a data system kernel?

what are its basic components?

algorithms/data structures/caching policies

what decisions should we make?

how to combine? how to optimize for hardware?

how many options?

data system design **complexity**

application

performance

budget

thousands of **options**

millions of **decisions**

billions of **combinations**

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let’s think together: a simple db kernel

a key-value system, each entry is a {key,value} pair

main operations: *put, get, scan, range scan, count*

workload has both reads (get, scan, range scan) *and writes (put)*

data

how to store and how to access data?

how to efficiently delete?

designing a simple key-value system:

what is the key/value?

are they stored together?

can read/write ratio change over time?

what to use? b-tree, hash-table, scans, skip-lists, zonemaps?

how to handle concurrent queries? million concurrent queries?

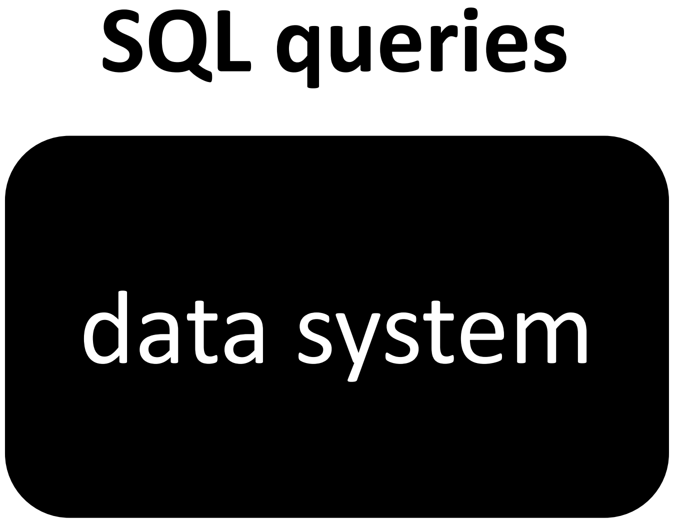
how to compress data?

how to exploit multi-core, SIMD, GPUs?

what happens if data does not fit in memory?

what happens if data does not fit in a node?

other challenges of a db system



SQL queries

data system

(much) more than 1 user?

ensure complete/correct answers?

protect data breaches and privacy?

robust performance?

what happens when move to the cloud?

hardware at massive scale

performance tradeoffs different

10GB app: 1% less memory in your machine so what?

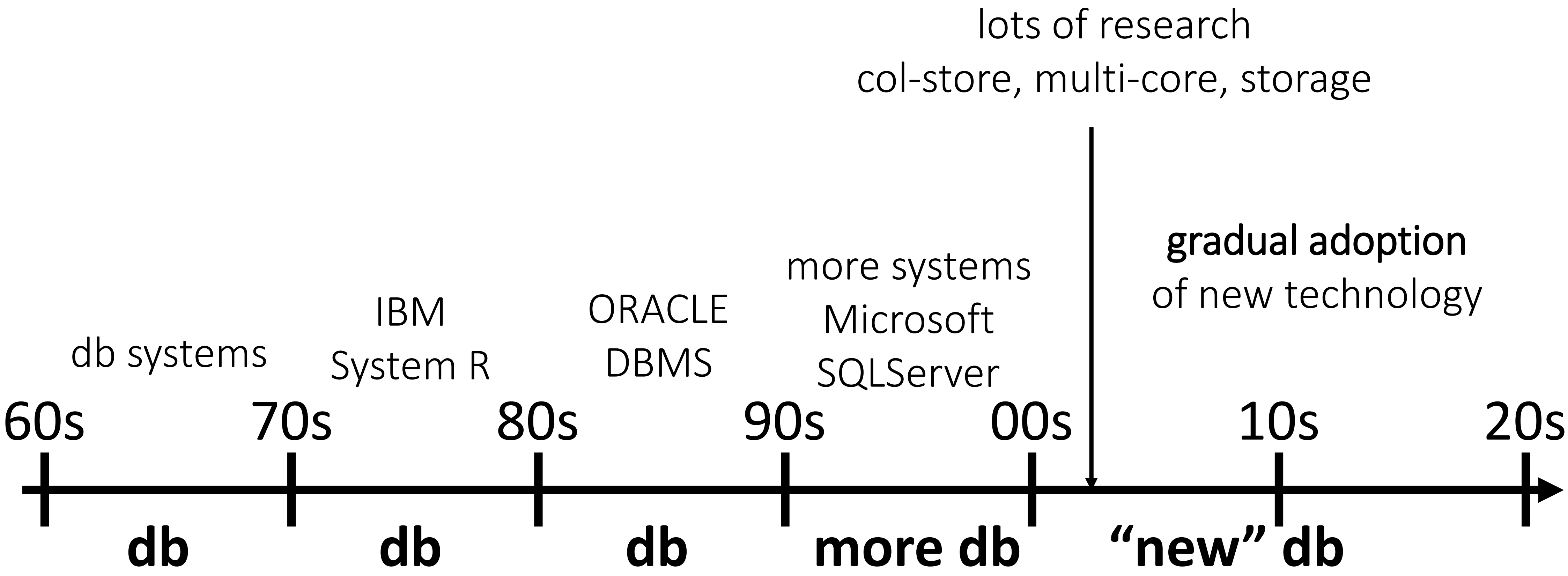
10GB app: 1% less memory in 1M instances 1M*10GB*1%=100TB!

~800k$ in today's price

what about security?

elasticity privacy scalability

db systems history line



lots of research

col-store, multi-core, storage

db systems

IBM
System R

ORACLE
DBMS

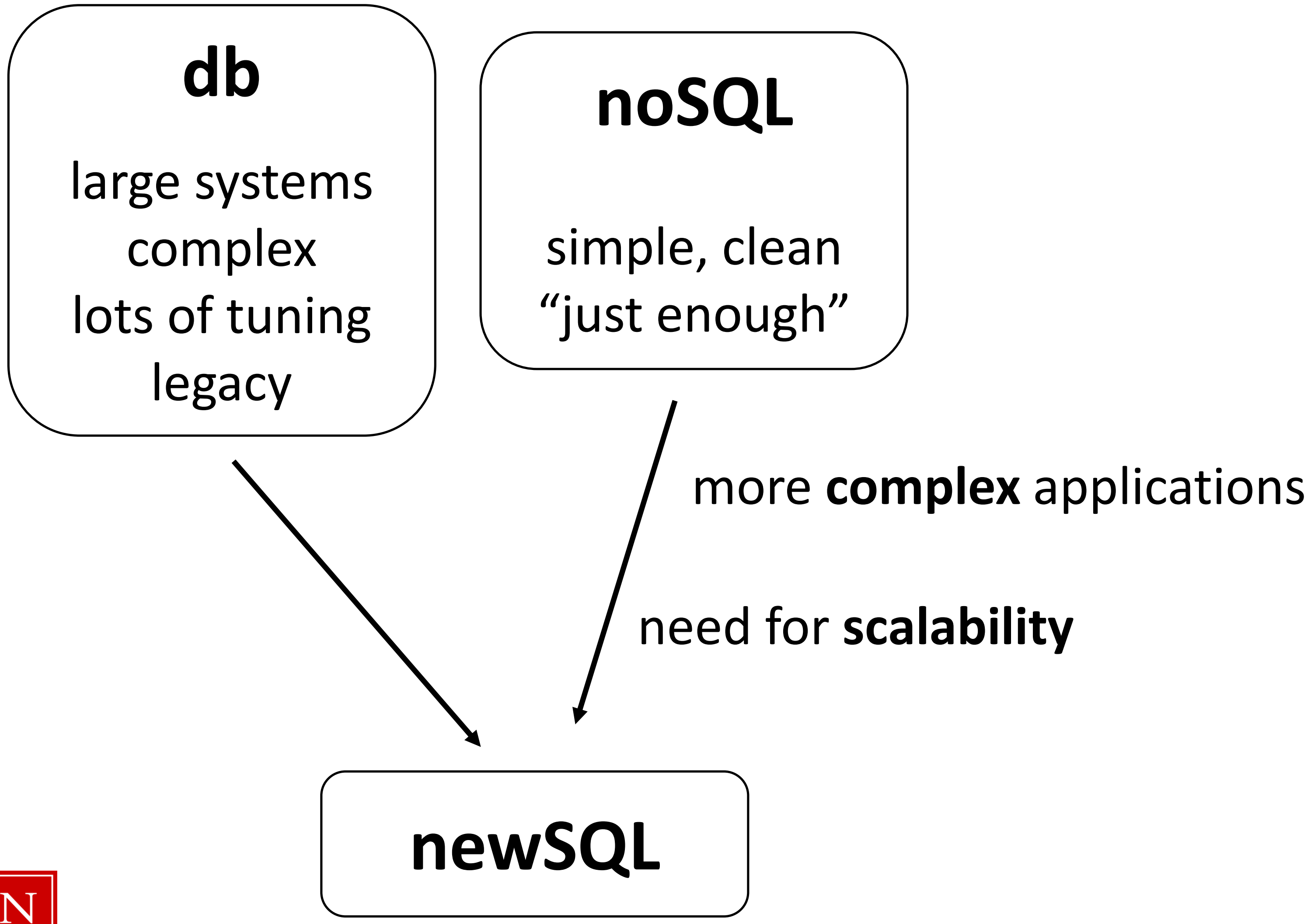
more systems
Microsoft
SQLServer

gradual adoption
of new technology

60s 70s 80s 90s 00s 10s 20s

db **db** **db** **more db** **“new” db**

the game of new technologies



db

large systems
complex
lots of tuning
legacy

noSQL

simple, clean
“just enough”

more **complex** applications

need for **scalability**

newSQL

what is ***really*** new?

CS591 more logistics

topics

storage layouts, solid-state storage, multi-cores, indexing, access path selection, HTAP systems, data skipping, adaptive indexing, time-series, scientific data management, map/reduce, data systems and ML, learned indexes

past but still relevant topics

relational systems, row-stores, query optimization, concurrency control, SQL

how did we end up to today’s systems?

no textbook – only research papers

class key goal

understand **system design tradeoffs**

design and **prototype** a system

with other **side-effects:**

sharpening your systems skills

(C/C++, profiling, debugging, linux tools)

data system designer & researcher

any business, any startup, any scientific domain

grading

class participation: 5%

reviews: 25% (long 15%, short 10%)

paper presentation: 25%

mid-semester project report: 10%

project: 35%

Piazza

all discussions & announcements

http://piazza.com/bu/spring2019/cs591a1/

also available on class website

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no
smartphones

no
laptop

Why?

there is enough evidence that laptops and phones slow you down

Your awesome TA!

Subhadeep, Postdoc

office: MCS 283

Prof. Manos Athanassoulis

name in greek: Μάνος Αθανασούλης

grew up in Greece
enjoys playing basketball and the sea

photo for VISA / conferences

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

Myrtos, Kefalonia, Greece

some awards:
Best of SIGMOD/VLDB papers
SNSF Postdoc Mobility Fellowship
IBM PhD Fellowship

http://manos.athanassoulis.net
Office: MCS 279
Office Hours: Tu/Th after class

how can I prepare?

1) Read background research material

- **Architecture of a Database System**. By J. Hellerstein, M. Stonebraker and J. Hamilton. Foundations and Trends in Databases, 2007
- **The Design and Implementation of Modern Column-store Database Systems**. By D. Abadi, P. Boncz, S. Harizopoulos, S. Idreos, S. Madden. Foundations and Trends in Databases, 2013
- **Massively Parallel Databases and MapReduce Systems**. By Shivnath Babu and Herodotos Herodotou. Foundations and Trends in Databases, 2013

2) Start going over the papers

class summary

2 classes per week / OH 4 days per week

each student

1 presentation/discussion lead + 2 reviews per week

(5 long and the rest short, can skip 3)

systems or research project + mid-semester report

what to do now?

A) read the syllabus and the website
B) register to piazza
C) register to gradescope
D) register for the presentation (week 2)
E) start submitting paper reviews (week 3)
F) go over the project (end of this week will be available)
G) start working on the mid-semester report (week 3)

survival guide

class website: http://manos.athanassoulis.net/classes/CS591/

piazza website: http://piazza.com/bu/spring2019/cs591a1/

presentation registration: https://tinyurl.com/CASCS591A1-presentations

gradescope entry-code: MR7ZD4

office hours: Manos (Tu/Th, 2-3pm), Subhadeep (M/W 2-3pm)

material: papers available from BU network

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Welcome to CS 591: **Data Systems Architectures!**

Prof. Manos Athanassoulis

mathan@bu.edu

next time: more detailed logistics and start with data systems design