

CS 591: Data Systems Architectures

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<https://midas.bu.edu/classes/CS591A1/>

no
smartphones



no
laptop



Why?

there is enough evidence that laptops and phones slow you down

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]

CS591 philosophy



cutting-edge research

question everything (to understand it better!)

interactive & collaborative

Understanding a design/system/algorithm ...

system

- component 1
- component 2
- component 3

algorithm

- step 1
- step 2
- step 3

why?
why not?

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

(otherwise we make ad hoc choices!)

Ask Questions!

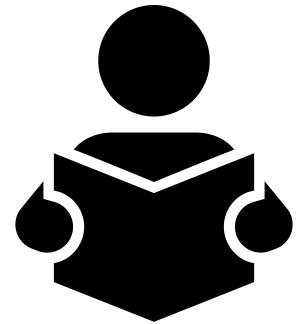


... and answer my questions!

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



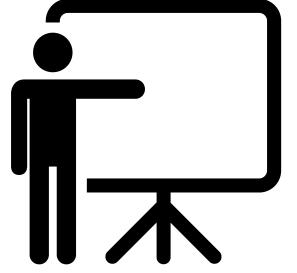
every class **1-2 papers to discuss in detail – presented by a student**
(background papers also available to provide more details)

read all of them!

write 8 reviews (10 papers will be reviewed, can skip 2)

answer one technical question (for the remaining papers)

Presentations



for every class, **1-2 students will be responsible for presenting** the paper (discussing all main points of a 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(s) will **prepare slides and questions**

Reviews



8 reviews and the rest single technical question

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?

single technical question

to make sure the heart of the paper is clearly understood

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

systems project

implementation-heavy C/C++ project

groups of 2

research project

groups of 3

pick a subject (list will be available)

design & analysis

experimentation



Project theme: NoSQL key-value stores

... are everywhere



Couchbase



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

- (1) has a clear plan by project proposal (5% - mid February)
- (2) has significant preliminary work done by mid-semester (5%)

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 Student 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
data systems for data science

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
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

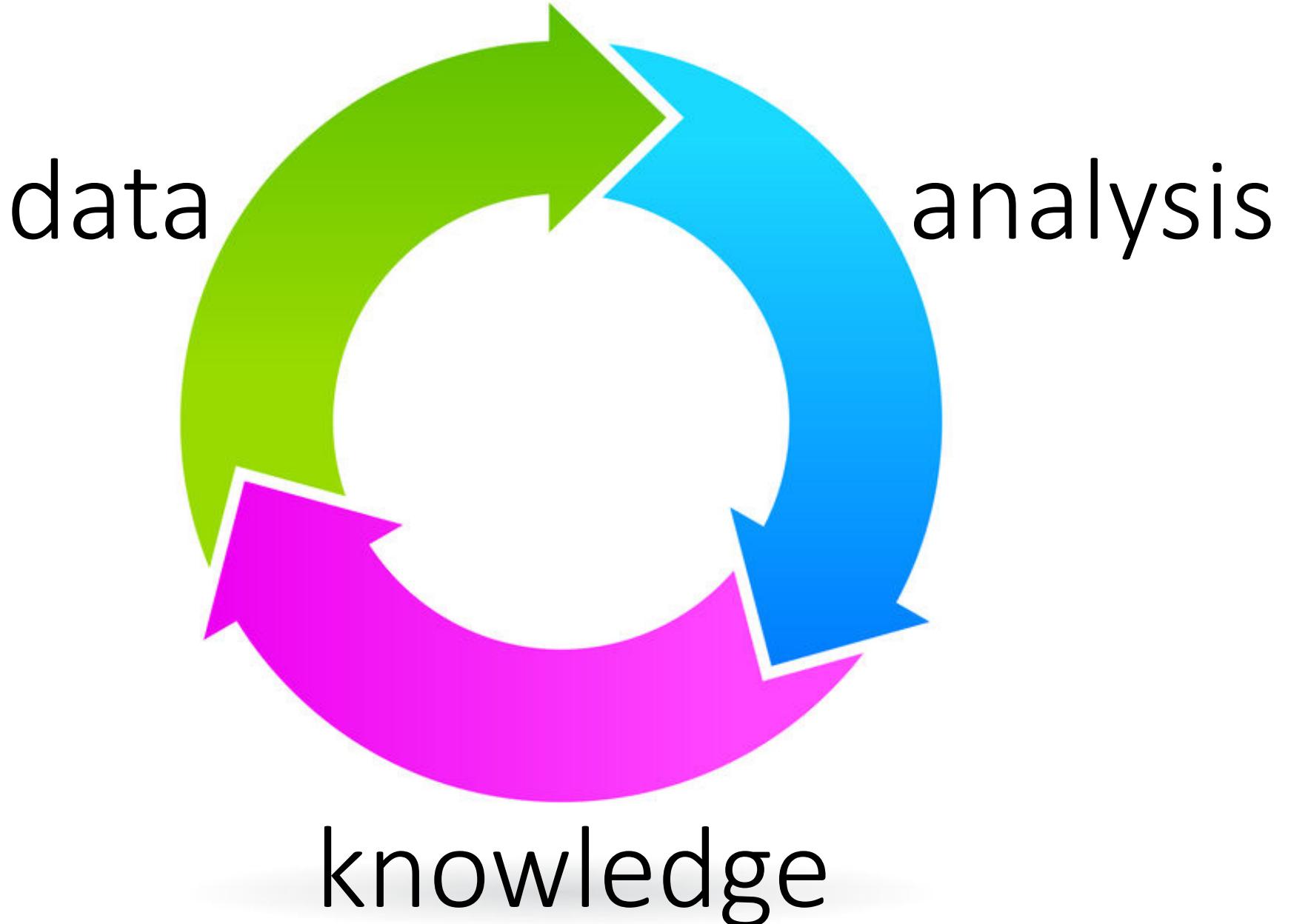
present and **discuss** research papers from students + talks from Manos + guest lectures



big data?

who doesn't have a lot of data?

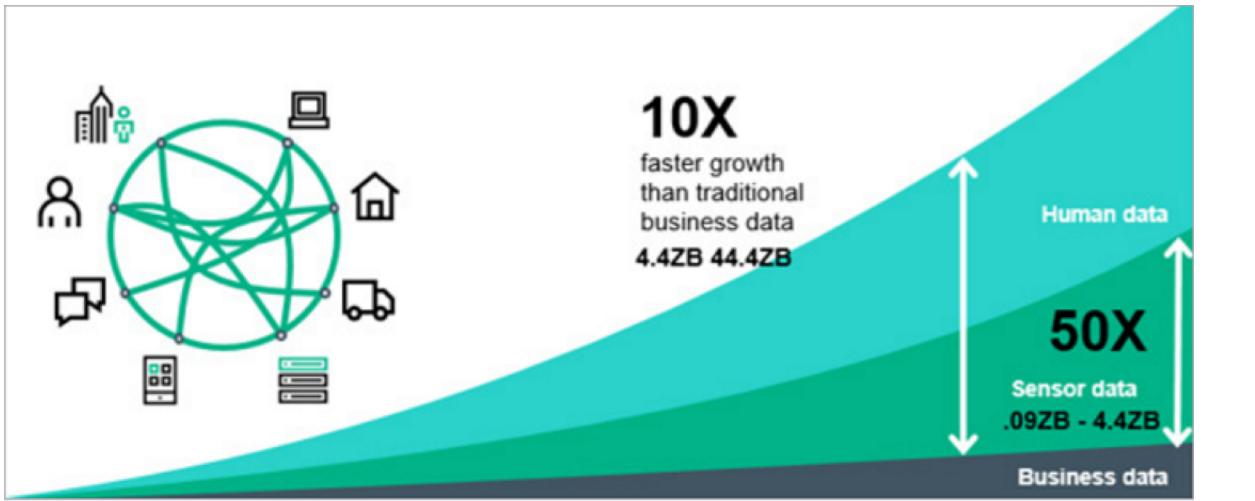
what is new?



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



data management skills needed



100s of entries

pen & paper

$10^3\text{-}10^6$ 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)

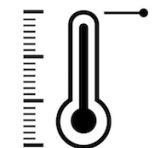
all of the above plus ...

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

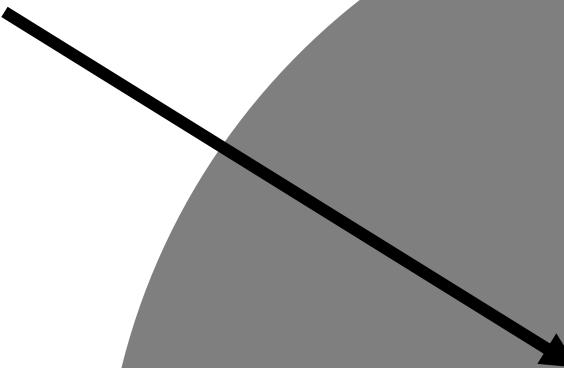
*not sure what we
are looking for*



data systems are
in the middle of this!

big data

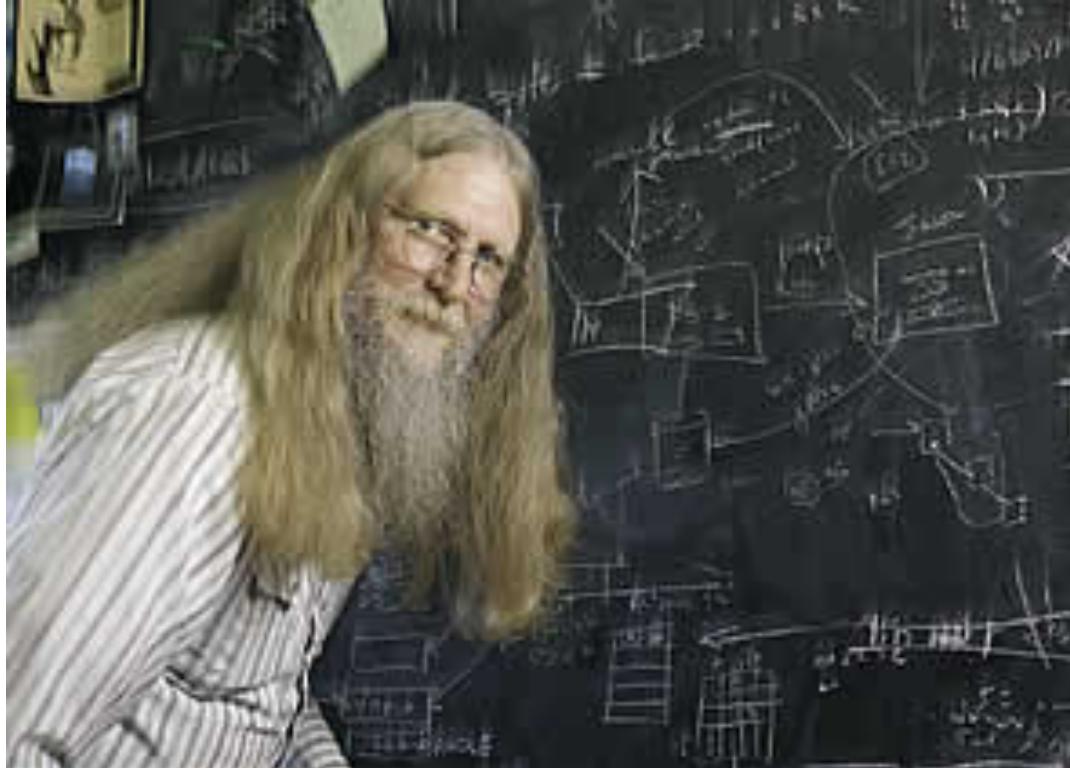
**data
systems**



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



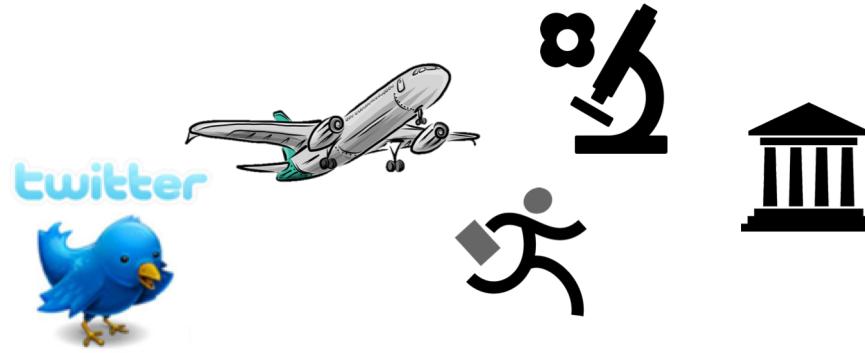
*“relational databases
are the foundation of
western civilization”*

Bruce Lindsay, IBM Research
ACM SIGMOD Edgar F. Codd Innovations award 2012

data systems are everywhere

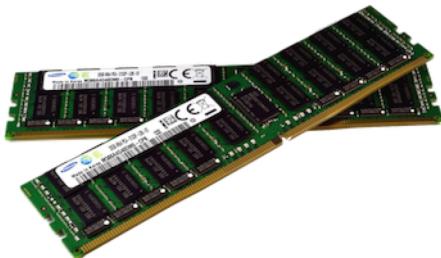


Microsoft



growing need for tailored systems

future



Why?



new applications



new hardware



more data

ORACLE®



Google

The big success of 5 decades of research

a declarative interface!

“ask and thou shall receive”

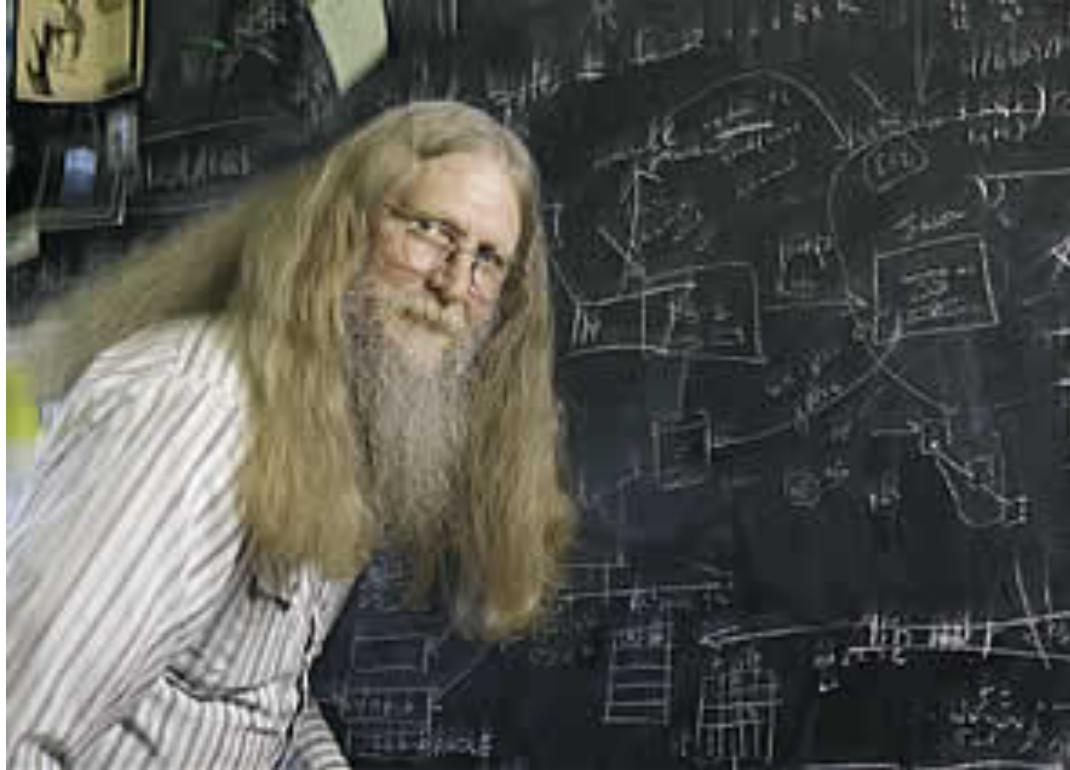


is this good? why?

ask ***what*** you want

data system

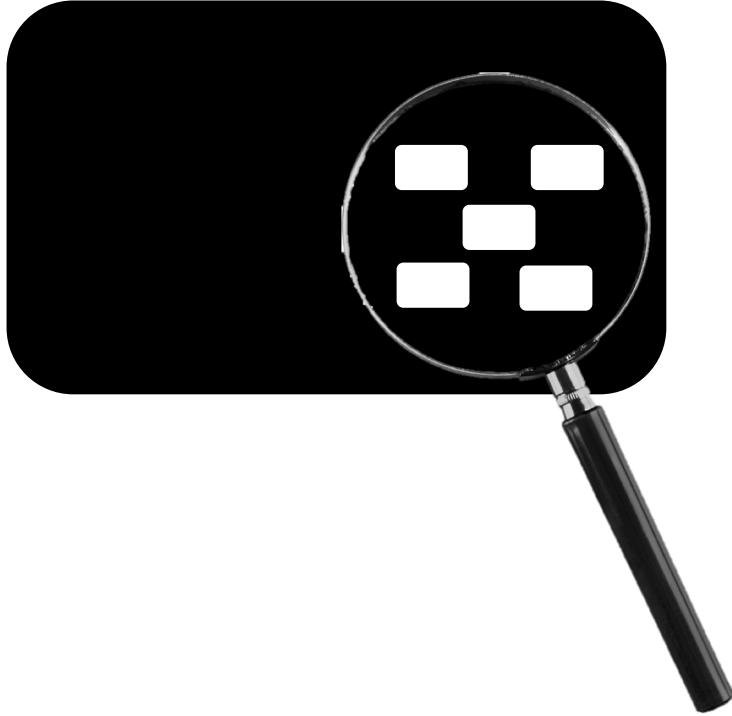
system decides ***how***
to store & access



*“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

how to design a data system kernel?

what are its basic components?

algorithms/data structures/caching policies

what decisions should we make?

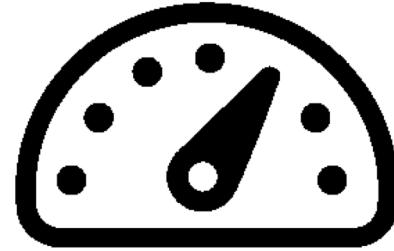
how to combine? how to optimize for hardware?

how many options?

data system design complexity



application



performance



budget

thousands of options
millions of decisions
billions of combinations

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 we 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

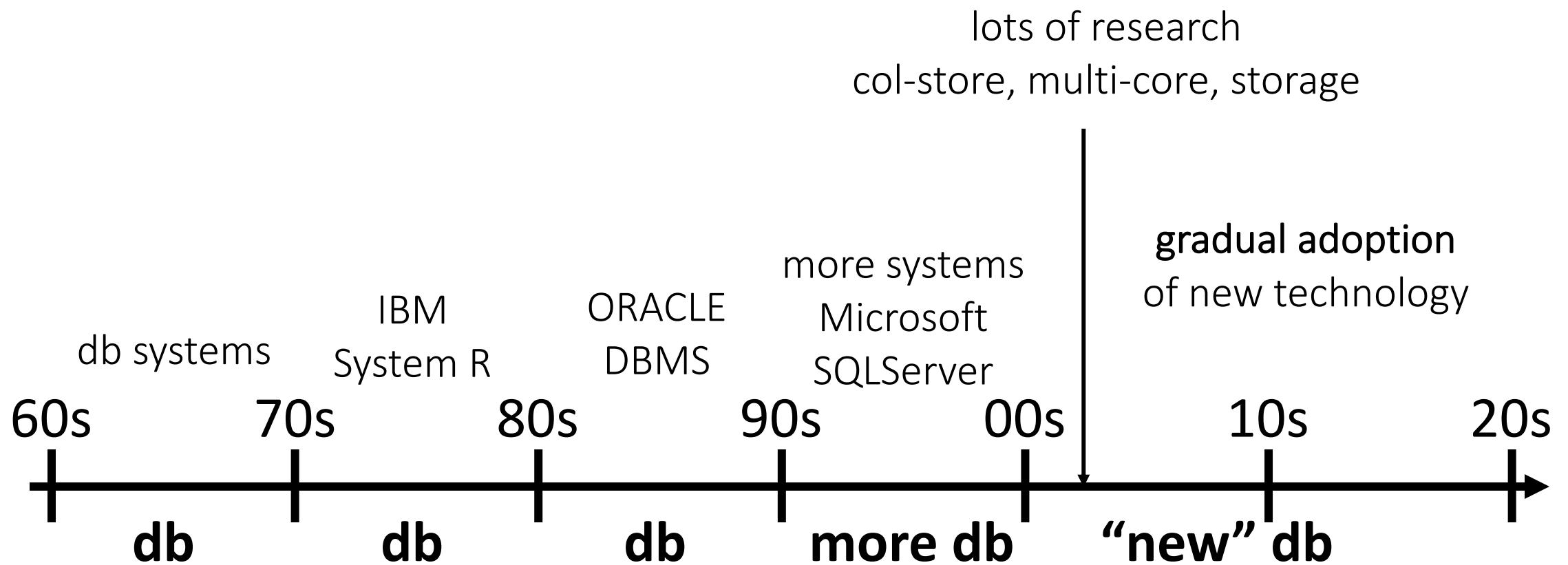
$1M * 10GB * 1\% = 100TB!$

$\sim 800k\$$ in today's price

what about security?

elasticity privacy scalability

db systems history line



the game of new technologies

db
large systems
complex
lots of tuning
legacy

noSQL
simple, clean
“just enough”

what is *really* new?



more **complex** applications
need for **scalability**

newSQL

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: 20%
technical questions: 5%
paper presentation: 25%
project proposal: 5%
mid-semester project report: 5%
project: 35%

Piazza



all discussions & announcements

<http://piazza.com/bu/spring2020/cs591a1/>

also available on class website

no
smartphones



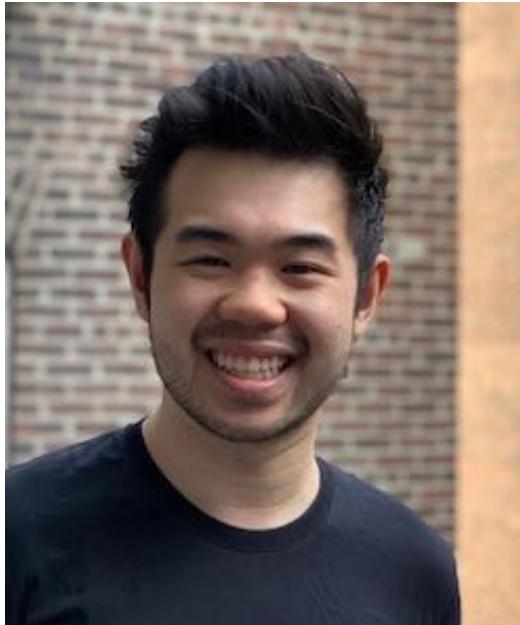
no
laptop



Why?

there is enough evidence that laptops and phones slow you down

Your awesome TAs!



Andy

office: MCS B08



Ju Hyoung

office: MCS 101A

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 Fellowship

IBM PhD Fellowship

<http://cs-people.bu.edu/mathan/>

Office: MCS 106

Office Hours: Tu/Th before 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 5 days per week

each student

1 presentation/discussion lead + 2 reviews/questions per week

systems or research project + proposal + 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 proposal (week 3)

survival guide

class website: <https://midas.bu.edu/classes/CS591A1/>

piazza website: <http://piazza.com/bu/spring2020/cs591a1/>

presentation registration: <https://tinyurl.com/S2020-CS591-presentations>

gradescope entry-code: 9568G3

office hours: Manos (Tu/Th, before class)

Andy (M/W 3-4pm), Ju Hyoung (M 11am-noon / F 3-4pm)

material: papers available from BU network

Welcome to CS 591: Data Systems Architectures!

Prof. Manos Athanassoulis

mathan@bu.edu

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