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CS 561: Data Systems Architectures

Prof. Manos Athanassoulis

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https://bu-disc.github.io/CS561/

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]

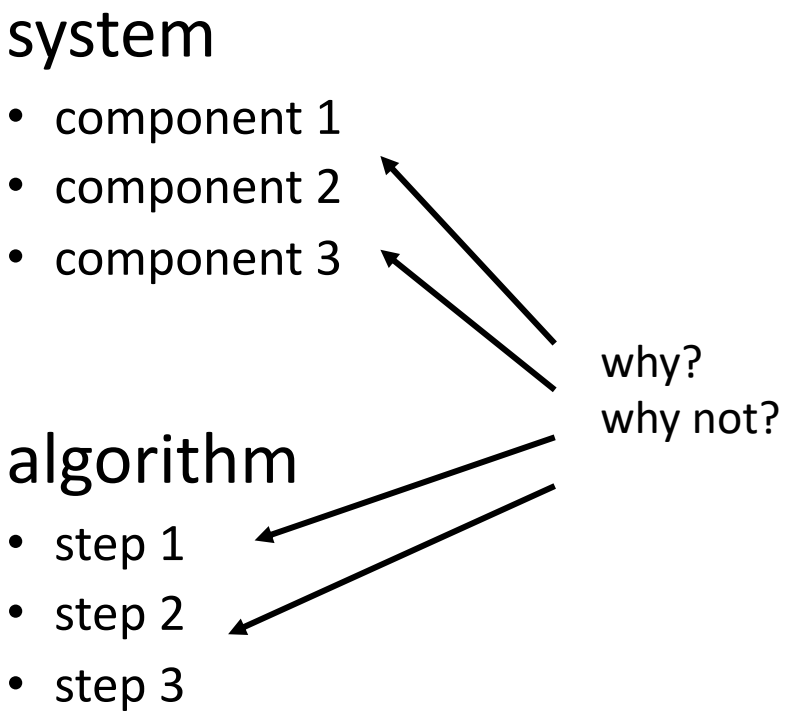
CS561 philosophy

cutting-edge research

question everything (to understand it better!)

interactive & collaborative

Understanding a design/system/algorithm …



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

(otherwise, we make ad hoc choices!)

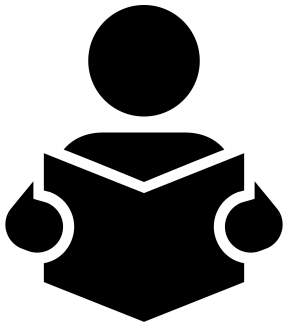
Ask Questions!

… 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

in some classes the discussion will be led by a group of students

so that, each student will present one paper during the semester

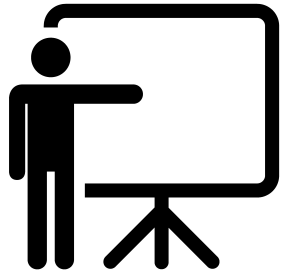
(background papers also available to provide more details)

read all of them!

write 4 reviews

answer one technical question per week (for a subset of the papers)

Presentations



2-4 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 <u>slides</u> and <u>questions</u>**

Reviews

4 reviews and the **6 technical questions**

(some weeks will be “free”!)

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

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

AND

project 0

A small implementation project
to sharpen dev skills

<u>independent project</u>

project 1

A project about the two fundamental
architectures: row-stores vs. column-stores

<u>groups of 3</u>

OR

systems project

groups of 3

implementation-heavy C/C++ project

research project

groups of 3

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

Research 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-March (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

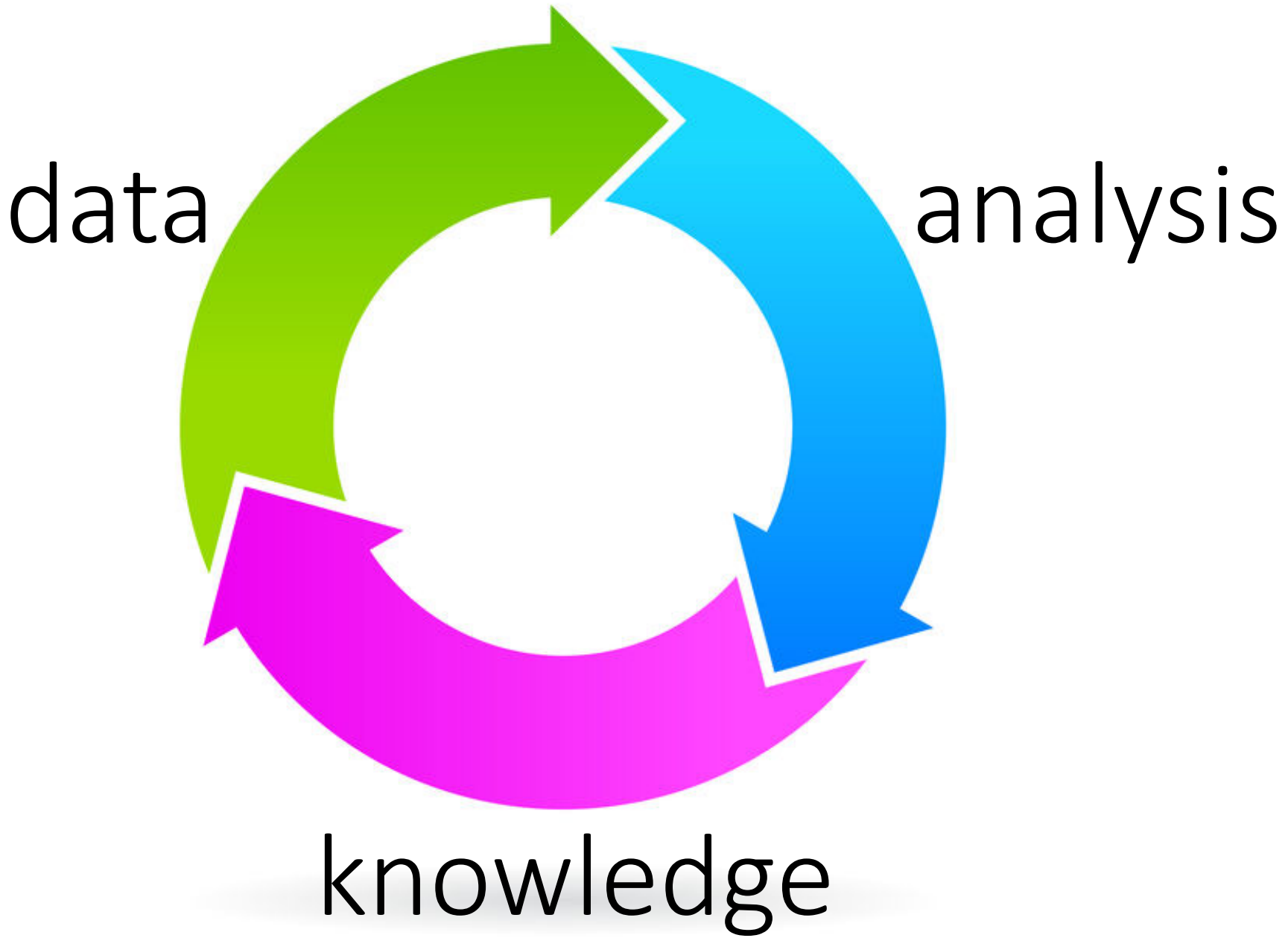
Class 4
intro to class project

Class 5 and beyond
present and **discuss** research papers from Manos + students + guest lectures

big data?

who doesn't have a lot of data?

what is new?



is data analysis new?

what is *really* new?

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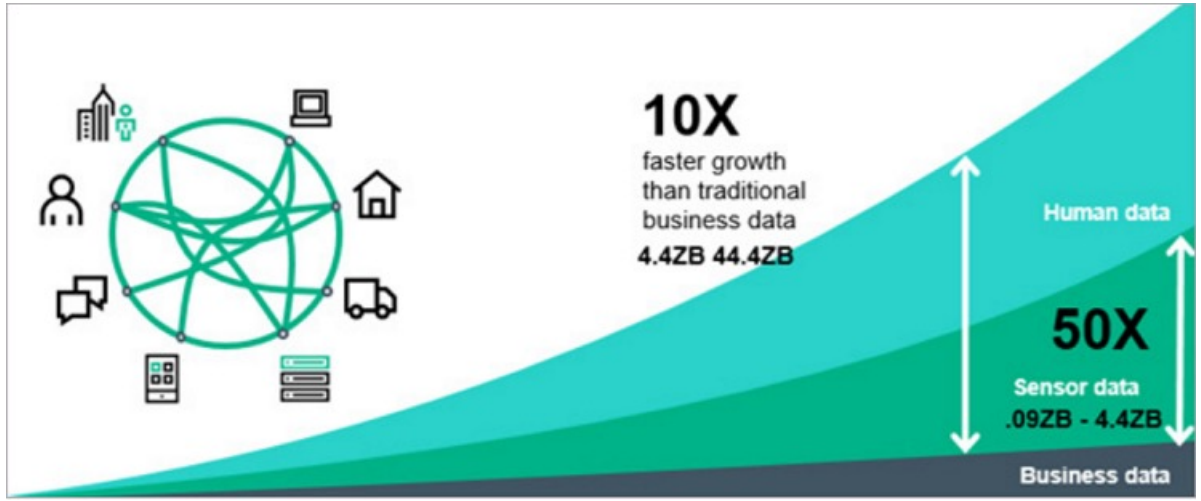


Every day, we create 2.5 exabytes* of data — 90% of the data in the world today has been created in the last two years alone.

[Understanding Big Data, IBM]

*exabyte = 10^9 GB

data management skills needed

100s of entries	**pen & paper**
10^3-10^6 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)

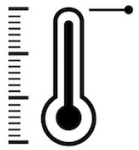
big data

(it's not only about size)

all of the above plus …

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

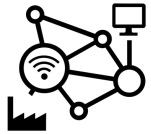

scientific experiments


sensors

social 

monitoring 


micro-payments

Internet-of-Things 

cloud 

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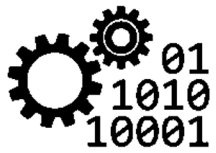
data analysis

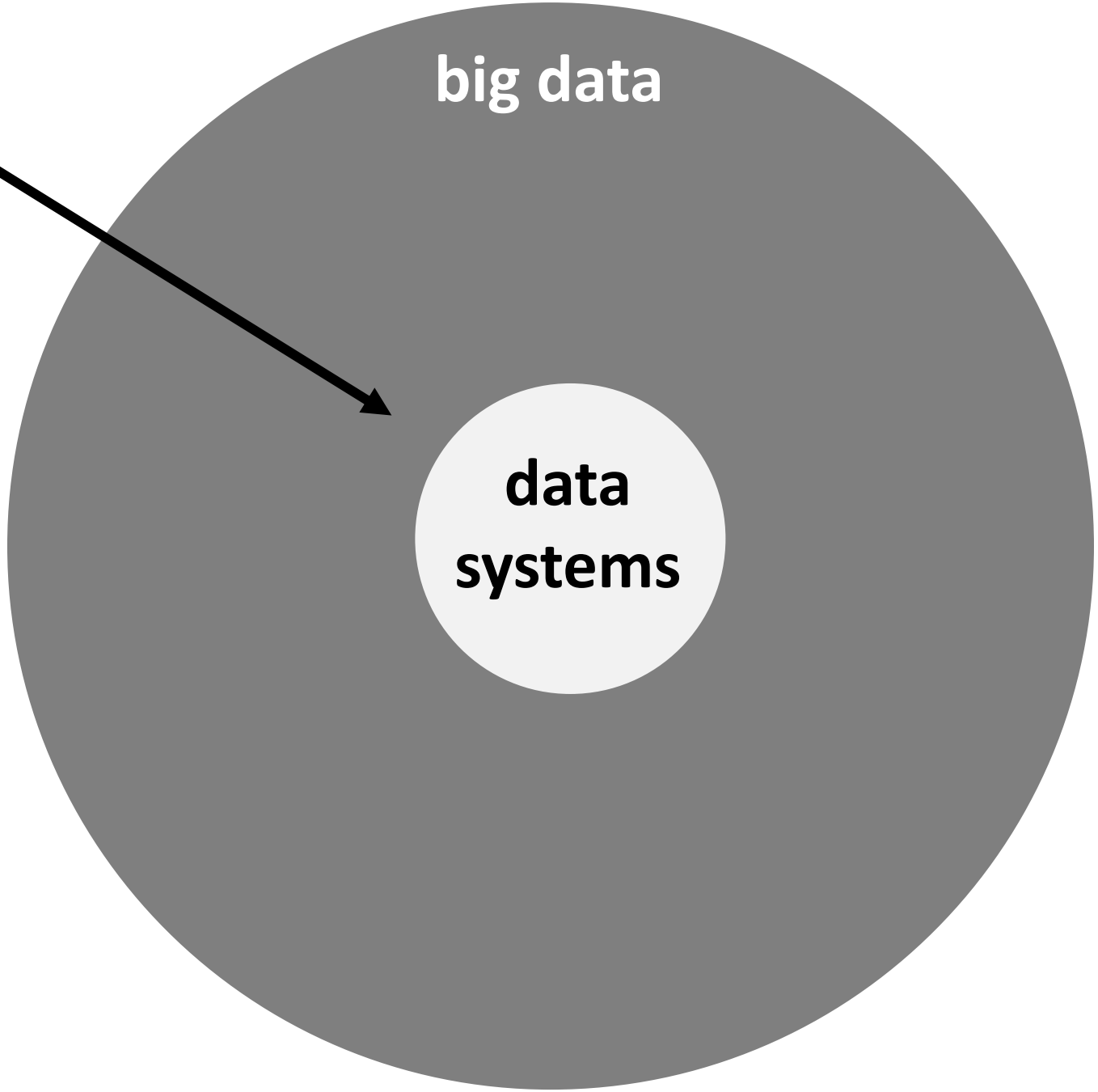
know what we are looking for



data exploration

not sure what we are looking for

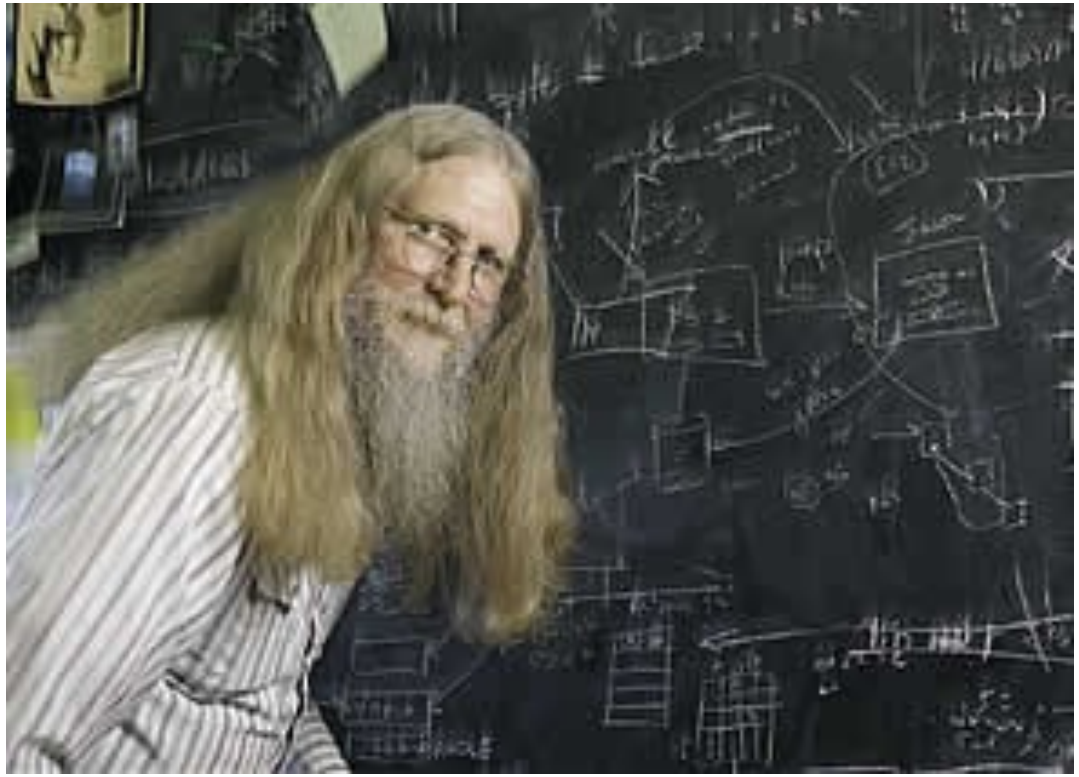
data systems are
in the middle of this!



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

Microsoft

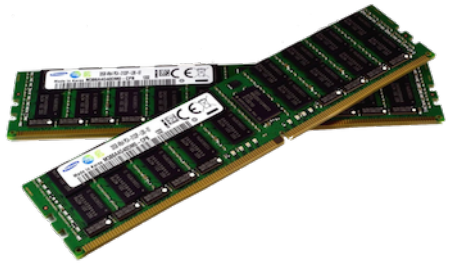
facebook

Google

twitter

growing need for tailored systems

future



Why?

new applications

new hardware

more data

The big success of 5 decades of research

a declarative interface!

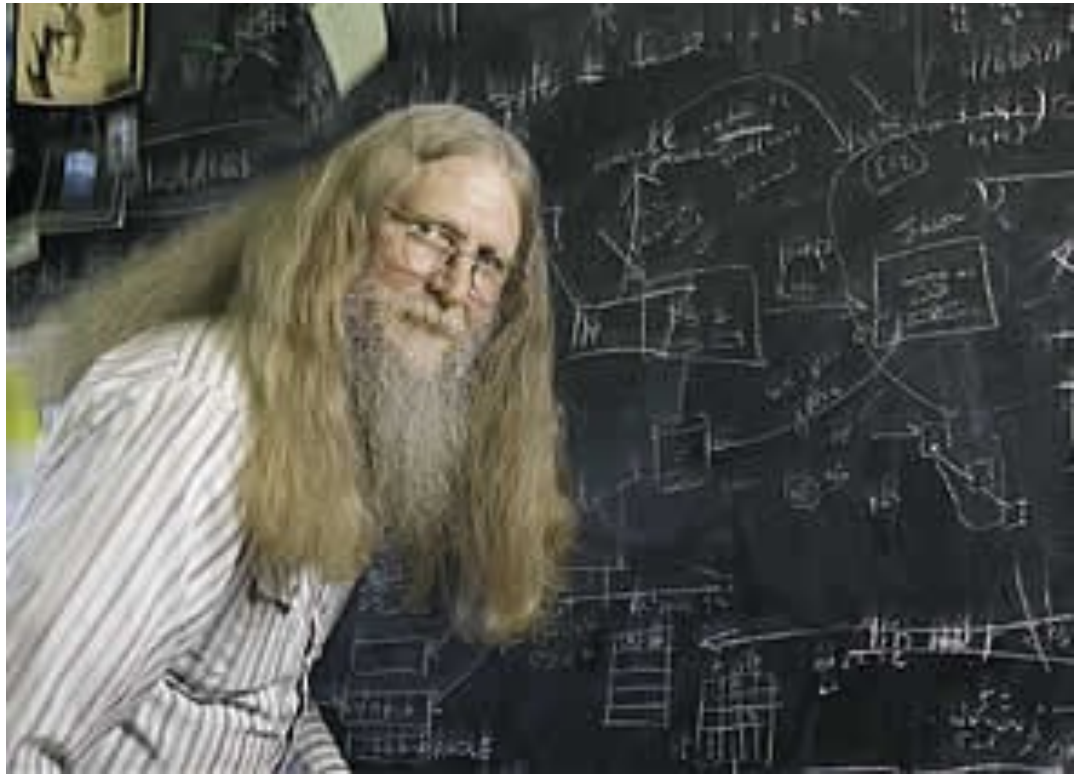
"ask and thou shall receive"

ask ***what*** you want

data system

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

is this good? why?

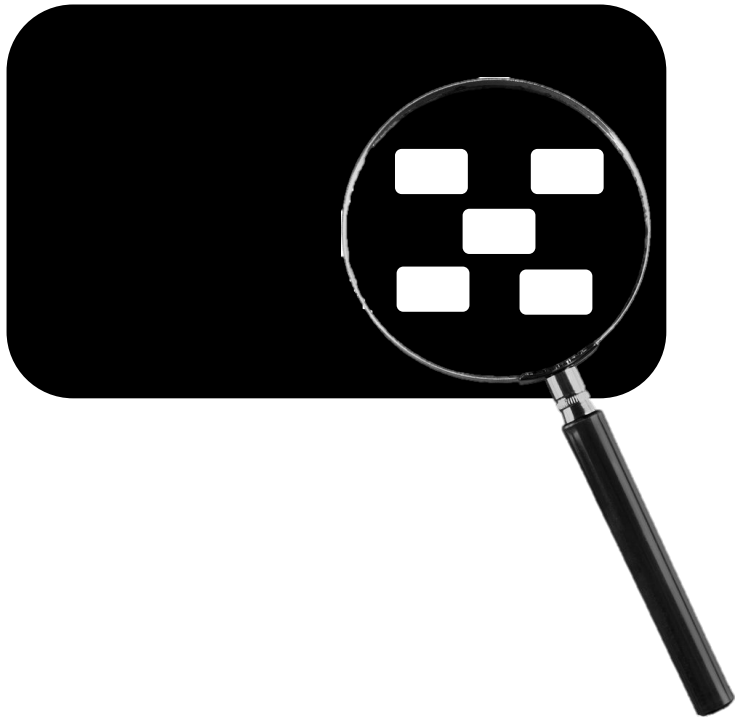


“three things are important in the database world: ***performance****,* ***performance****,* *and* ***performance****”*

Bruce Lindsay, IBM Research

ACM SIGMOD Edgar F. Codd Innovations award 2012

CS561: 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

(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?

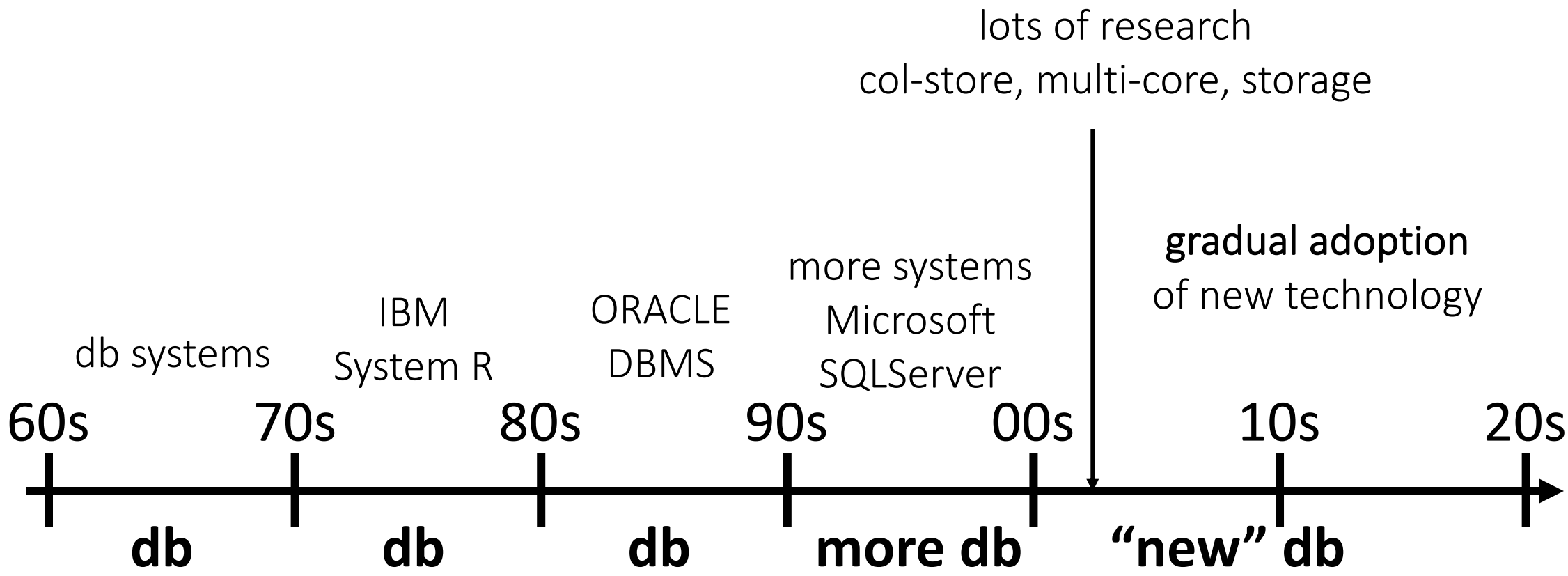
10GB app: 1% less memory in 1M instances — 1M*10GB*1%=100TB!

~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"

more **complex** applications

need for **scalability**

newSQL

what is ***really*** new?

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CS561 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%

project 0: 10%

project 1: 10%

reviews: 8%

technical questions: 12%

paper presentation: 15%

project proposal: 5%

mid-semester project report: 5%

project: 30%

Piazza

all discussions & announcements

https://piazza.com/bu/spring2022/cs561

also available on class website

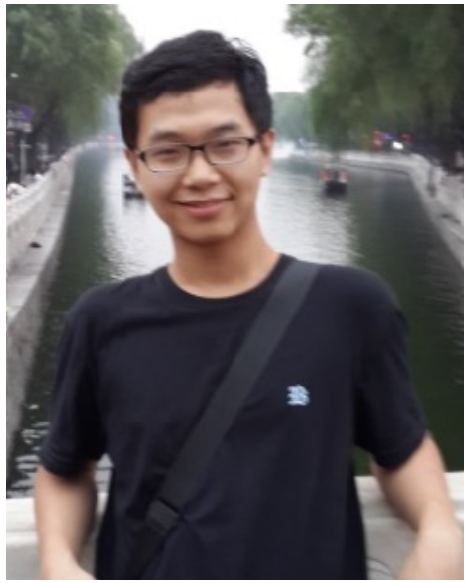
no smartphones

no laptop

Why?

there is enough evidence that laptops and phones slow you down

Your awesome TAs!



Zichen

Aneesh

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
NSF CRII Award
Facebook Faculty Fellowship

http://cs-people.bu.edu/mathan/
Office: MCS 106
Office Hours: T/Th 2-3pm

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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+Labs 5 days per week

each student

1 presentation/discussion lead + 1 review/question per week

project 0 + project 1 + systems or research project

proposal + mid-semester report + final report/presentation

what to do now?

A) read the syllabus and the website
B) register to piazza + gradescope
C) start working on project 0
D) register for the presentation (week 2)
E) start submitting paper reviews/answering tech. questions (week 3)
F) go over the project (end of next week will be available)
G) start working on the proposal (week 3)

survival guide

class website: https://bu-disc.github.io/CS561/

piazza website: https://piazza.com/bu/spring2022/cs561

presentation registration: https://tinyurl.com/S22-CS561-presentations

gradescope: https://www.gradescope.com/courses/342653 (**code in Piazza**)

office hours: Manos (T/Th 2-3pm)
Zichen, Aneesh (see in Piazza)

material: papers available from BU network

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Welcome to CS 561: Data Systems Architectures!

Prof. Manos Athanassoulis

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