CS460: Intro to Database Systems

Database System Architectures

Instructor: Manos Athanassoulis

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

Today

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

logistics, goals, admin

database systems architectures

project details

Course Scope

A detailed look “under the hood” of a DBMS

why?

applications writers, data scientists

database researchers, db admins

they all *understand* the internals

there is a huge need for database experts

data-intensive applications

big data workflows

Course Scope: Practical Side

use

benchmark

understand

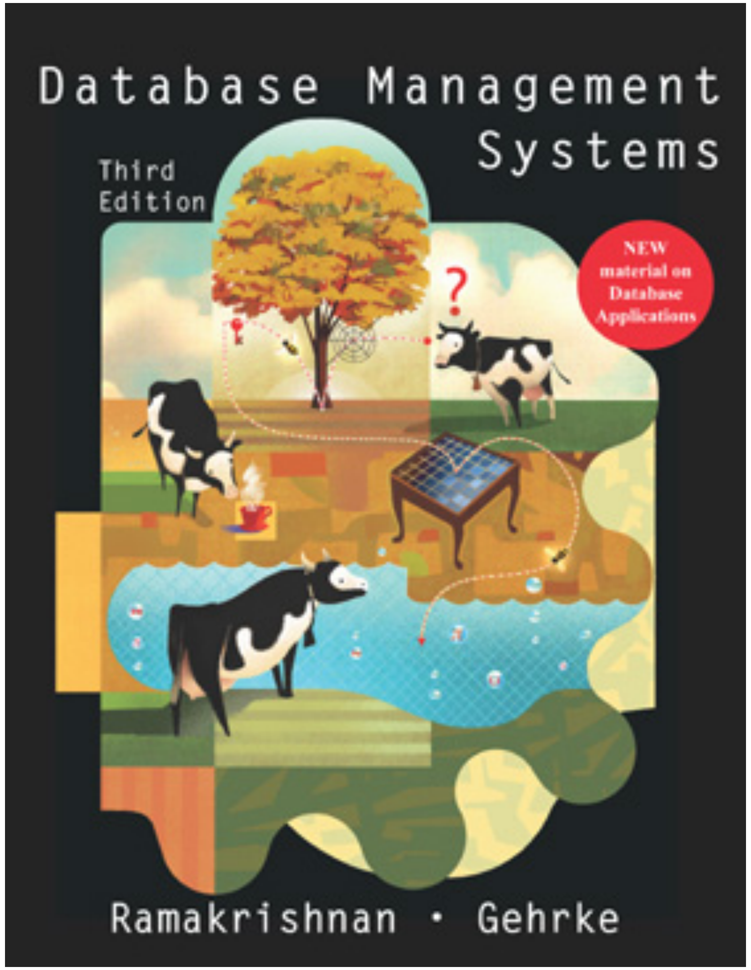
database systems!

More details when discussing the project!

Readings

“Cowbook”

by Ramakrishnan & Gehrke


Database Management Systems
Third Edition
NEW material on Database Applications
Ramakrishnan • Gehrke

Additional Readings

Architecture of a Database System, by J. Hellerstein, M. Stonebraker and J. Hamilton

The Design and Implementation of Modern Column-store Database Systems, by D. Abadi, P. Boncz, S. Harizopoulos, S. Idreos, S. Madden

Modern B-Tree Techniques, by Goetz Graefe, *Foundations and Trends in Databases, 2011*

+research papers

Evaluation

Class Participation: 5%

TopHat & In-class discussion

Collaborative Notes

3-4 students take notes (2 days after class anybody can augment it)
Shared Google doc: https://tinyurl.com/CS460-F20-Notes
[top part of website as well]

Enroll right after class!

Offline Content Questions

within 24-48 hours of each class we will post more questions

Evaluation

Class Participation: 5%

Written Assignments: 25%

Throughout the semester

7 deadlines spread across the semester [check the website]

Topics:

ER model / Relational Model / Relational Algebra

SQL / Normalization

Storage / Disk / Indexing

Transactions / Recovery

Evaluation

Class Participation: 5%

Written Assignments: 25%

Programming Assignments: 35%

Three assignments throughout semester

[more details later today]

Evaluation

Class Participation: 5%

Written Assignments: 25%

Programming Assignments: 35%

Midterm 1: 15%

Midterm 2: 20%

(more details soon)

Evaluation

Class Participation: 5%

Written Assignments: 25%

Programming Assignments: 35%

Midterm 1: 15%

Midterm 2: 20%

SQL Hands-On Test (bonus): 5%

Office Hours

All OH are online

Manos

M/Th @ 9:30am

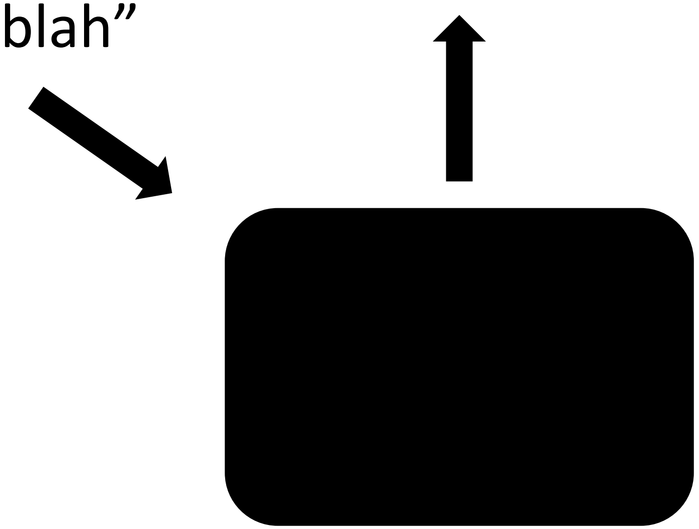
TAs

announced in Piazza

Database Systems

there you go

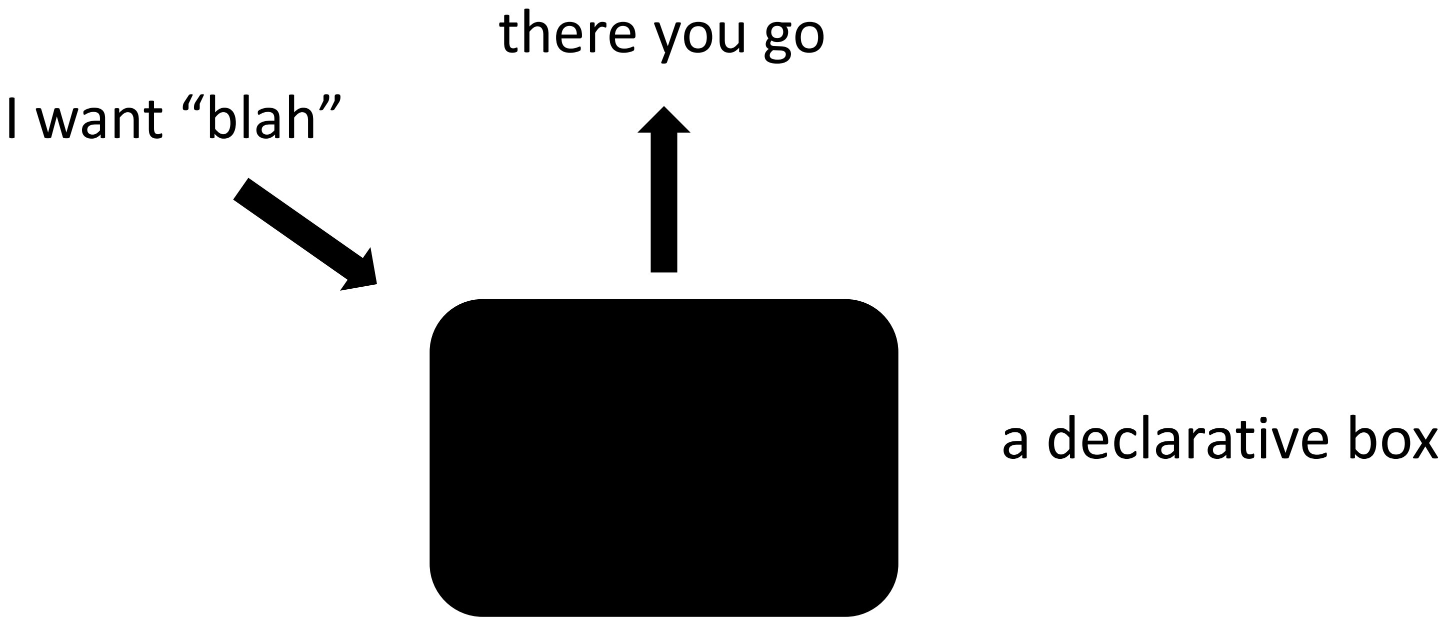
I want "blah"



a declarative box

why having a declarative box is useful?

Database Systems



application and **backend** development are independent collection of algorithms & data structures

multiple ways to do the same thing

optimization: dynamically decide which to use

how?

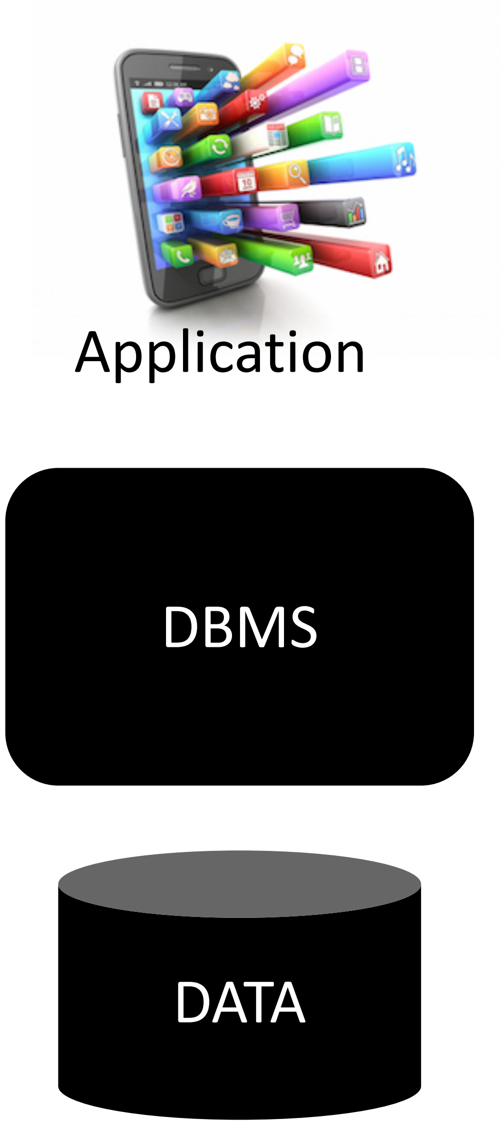
collection of algorithms & data structures

multiple ways to do the same thing

optimization: dynamically decide which to use

how? understand & model alternatives

data management goals

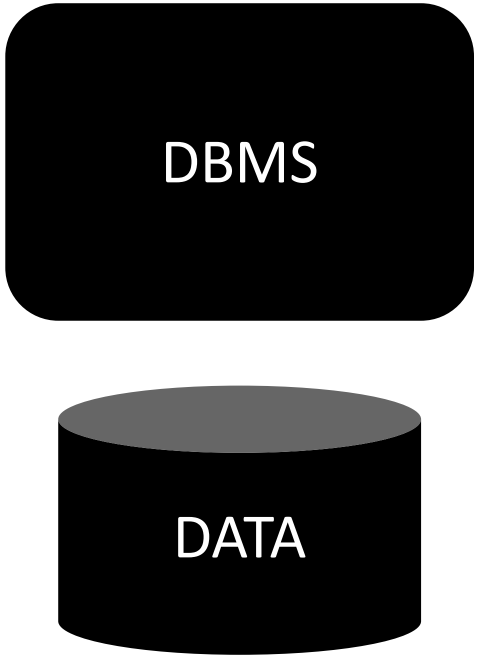


data management goals

Application

monetary cost

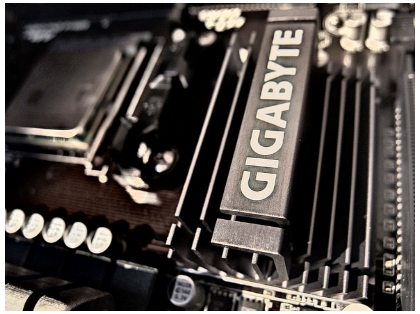
performance



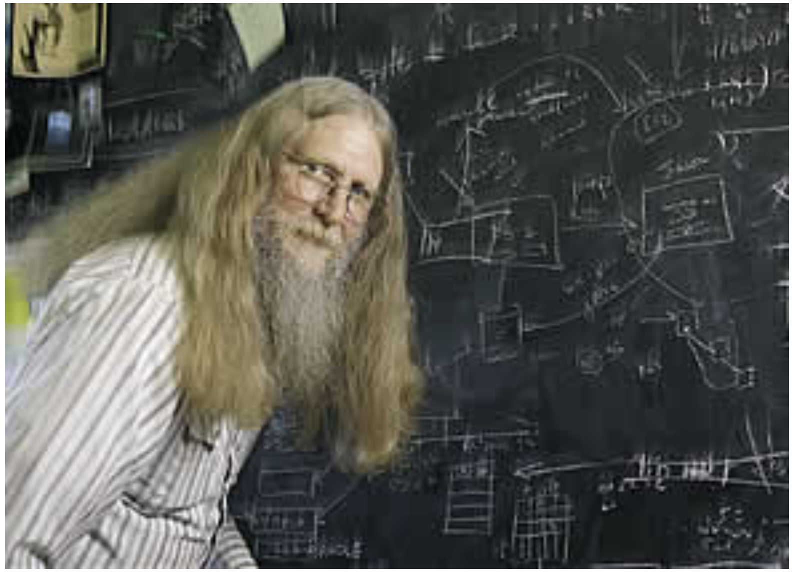
DBMS

DATA

energy



hardware

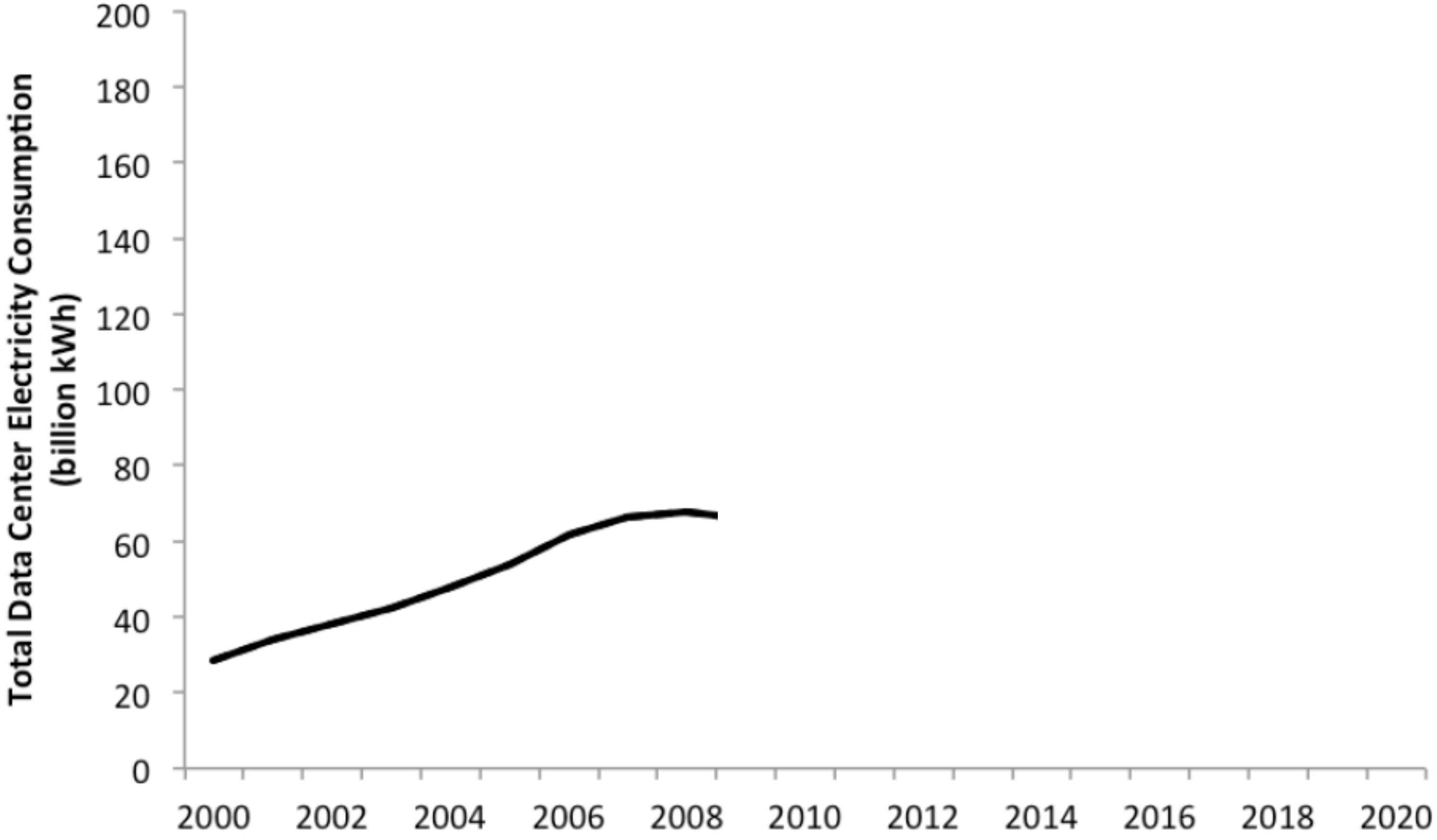


"three things are important in the database world: ***performance, performance,*** *and* ***performance****"*

Bruce Lindsay, IBM Research

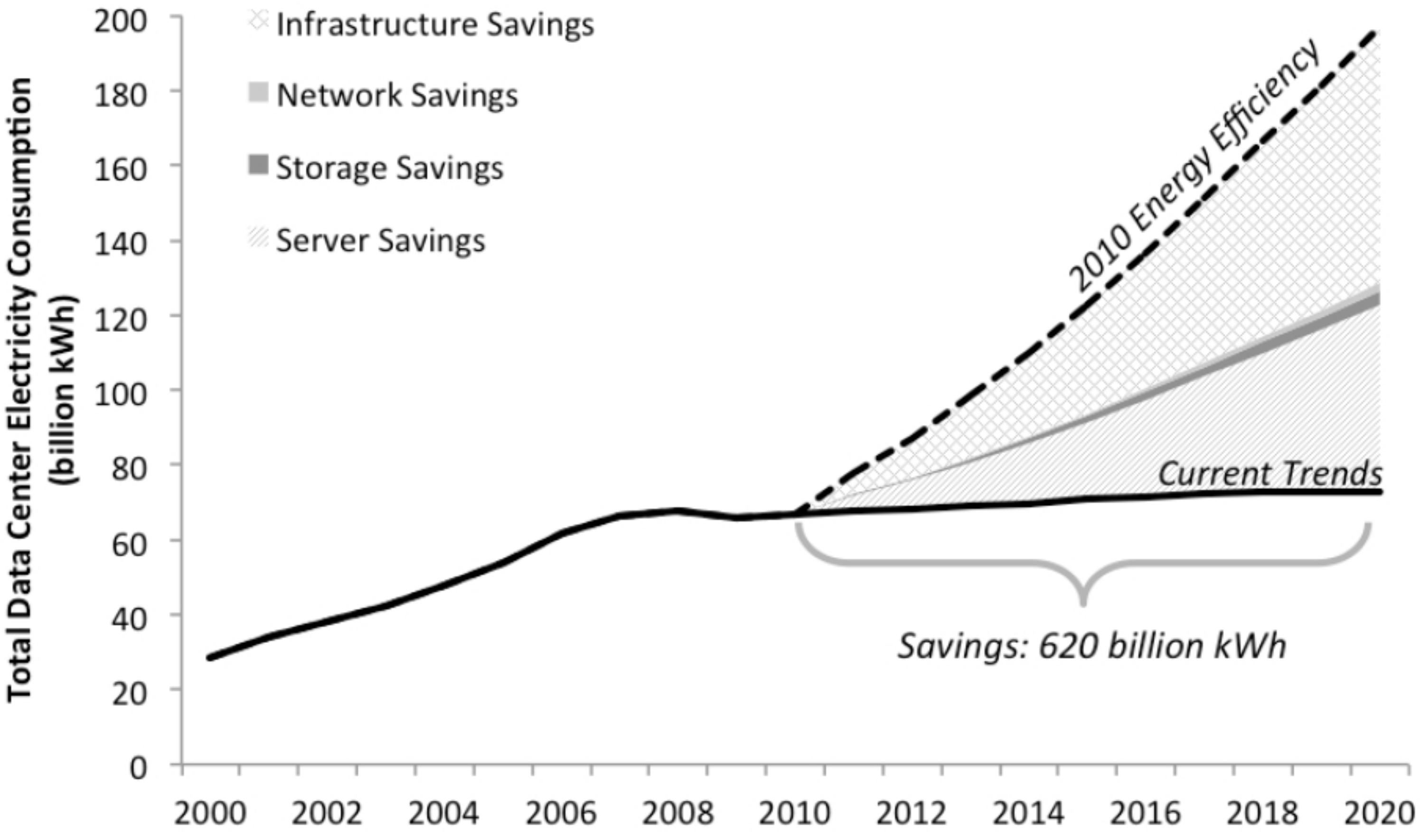
ACM SIGMOD Edgar F. Codd Innovations award 2012

but



datacenterknowledge.com, 2016

but



datacenterknowledge.com, 2016

but

new hardware in the last 20 years

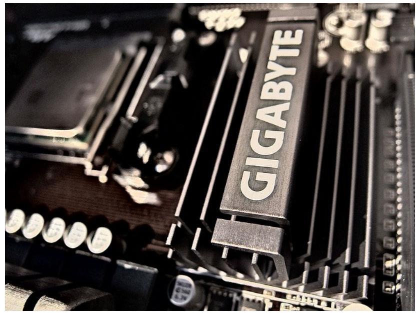
multi-core processors

multi-level cache memories

flash drives

SIMD instructions

…



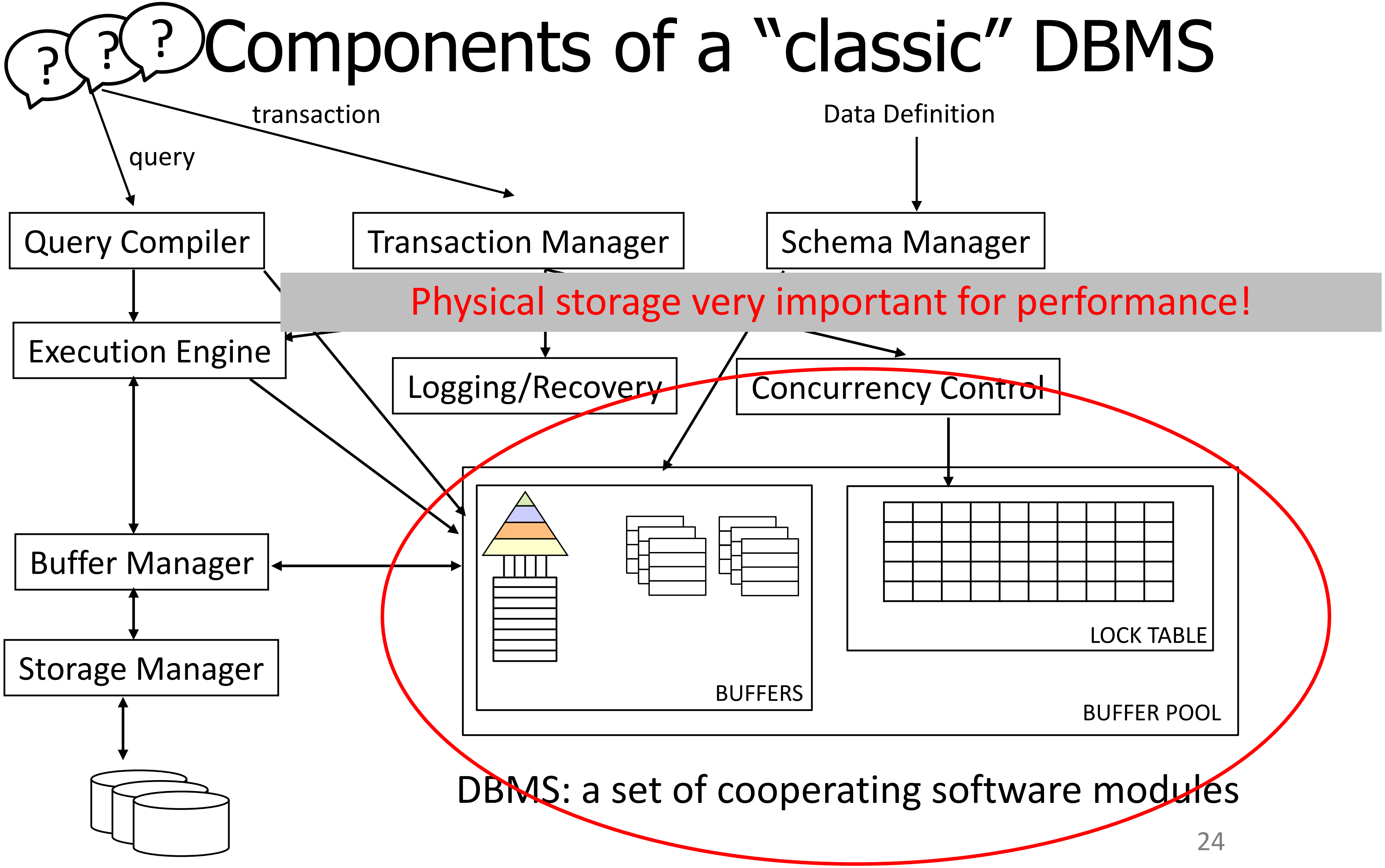
CS460

What is inside?

How it works?

performance on
a declarative box

Components of a “classic” DBMS



Physical storage very important for performance!

DBMS: a set of cooperating software modules

Some questions for today

how can we physically store our (relational) data?

how to efficiently access the data?

does that affect the way we ***ask*** queries?

does that affect the way we ***evaluate*** queries?

does that affect the way we apply ***updates***?

how to physically store data?

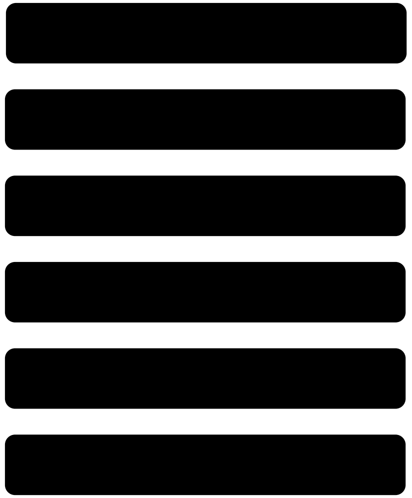
what is a relation?

a table with rows & columns!

how to physically store it?

how to physically store data?

one row at a time



how to efficiently access data?

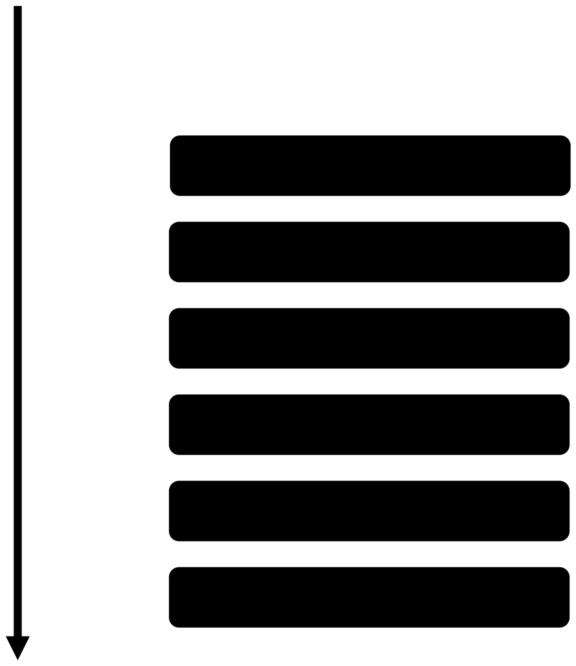
how to retrieve rows:

if I am interested in the average GPA of <u>all students</u>?

if I am interested in the GPA of <u>student A</u>?

how to efficiently access data?

Scan the whole table



if I am interested in most of the data

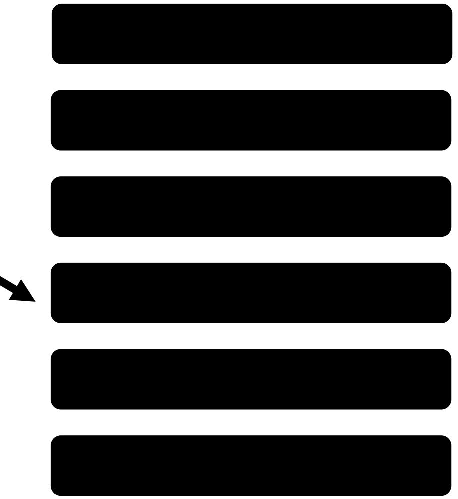
how to efficiently access data?

how to retrieve rows:

if I am interested in the average GPA of all students?

if I am interested in the GPA of student A?

how to efficiently access data?



Ask an *oracle* to tell me where is my data

if I am interested in a single row

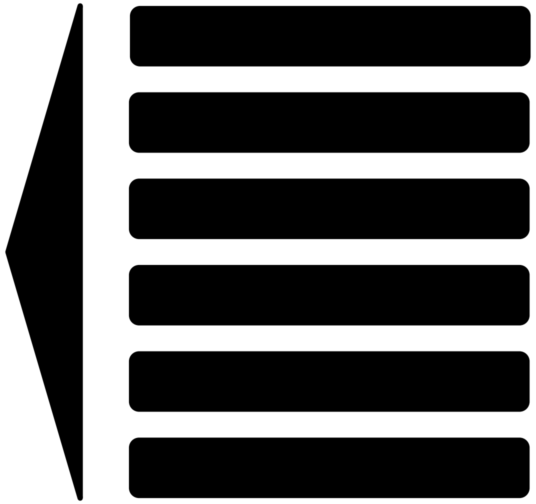
how to efficiently access data?

what is an *oracle* or *index*?

a data structure that given a value (e.g., student id)

returns location (e.g., row id or a pointer)

with less than O(n) cost ideally O(1)!



e.g., B Tree, bitmap, hash index

how to efficiently access data?

Scan vs. Index

How to choose?
Model!

What are the parameters?

data size
index traversal cost
access cost (random vs. sequential)
result set size ("selectivity")

how to efficiently access data?

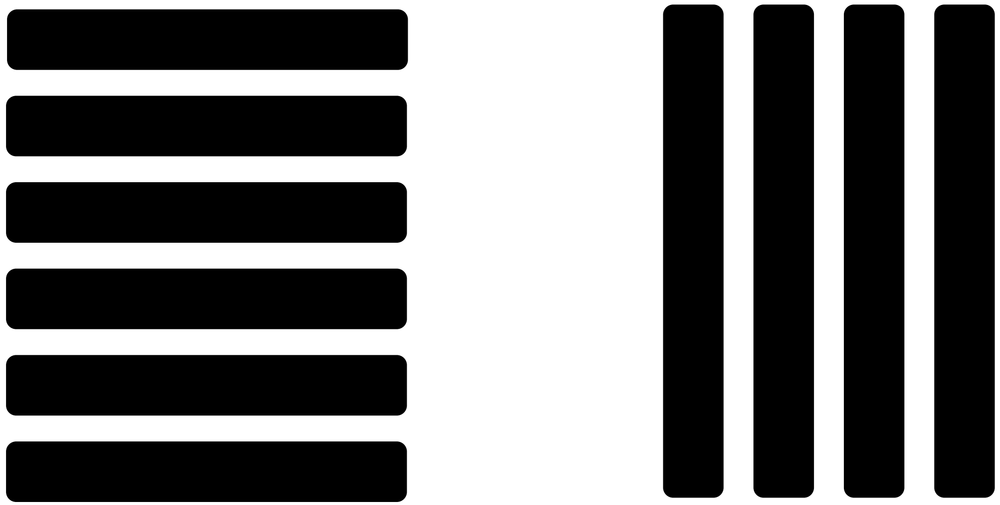
Scan vs. Index

Scan: many rows

Index: few rows

how to physically store data?

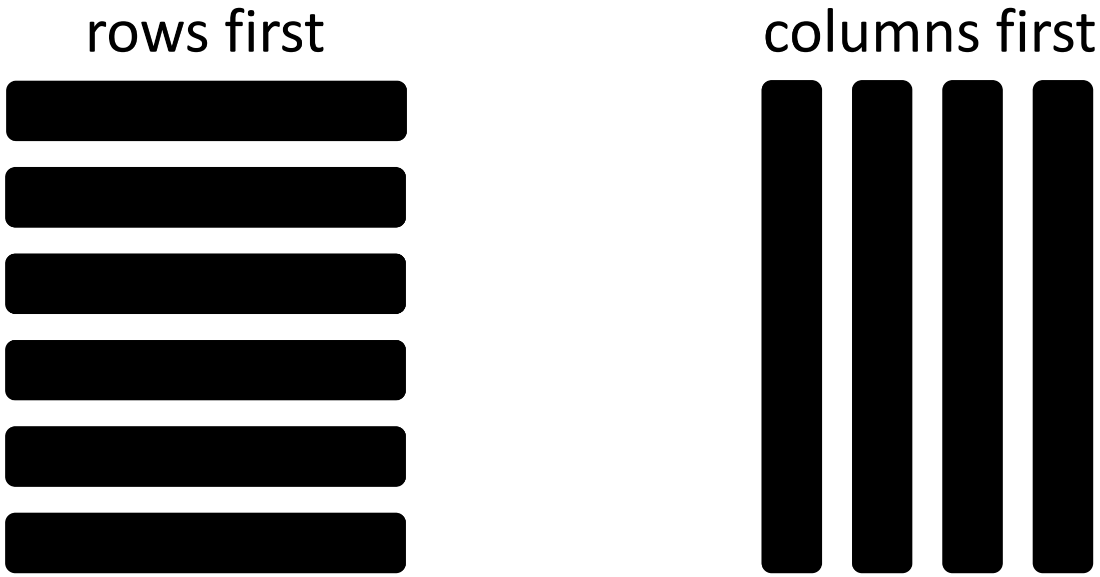
is there another way?



one row at a time

columns first

how to efficiently access data?



if I want to read an entire single row?

if I want to find the name of the younger student?

if I want to calculate the average GPA?

if I want the average GPA of all students with CS Major?

how to efficiently access data?

Rows vs. Columns

Rows: many attributes+few rows

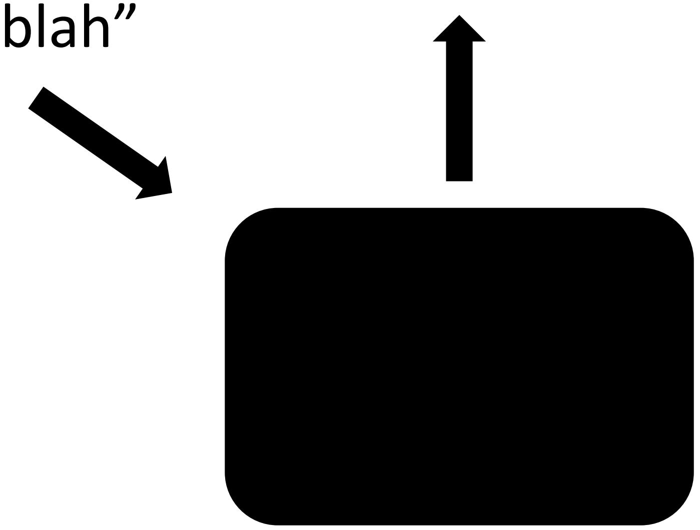
Columns: few attributes+lots of rows

does that affect the way we ***ask*** queries?

No!

there you go

I want “blah”



a declarative box

does that affect the way we ***evaluate*** queries?

Query Engine *is* different

row-oriented systems (”row-stores”)
move around rows

column-oriented systems (”column-stores”)
move around columns

does that affect the way we ***evaluate*** queries?

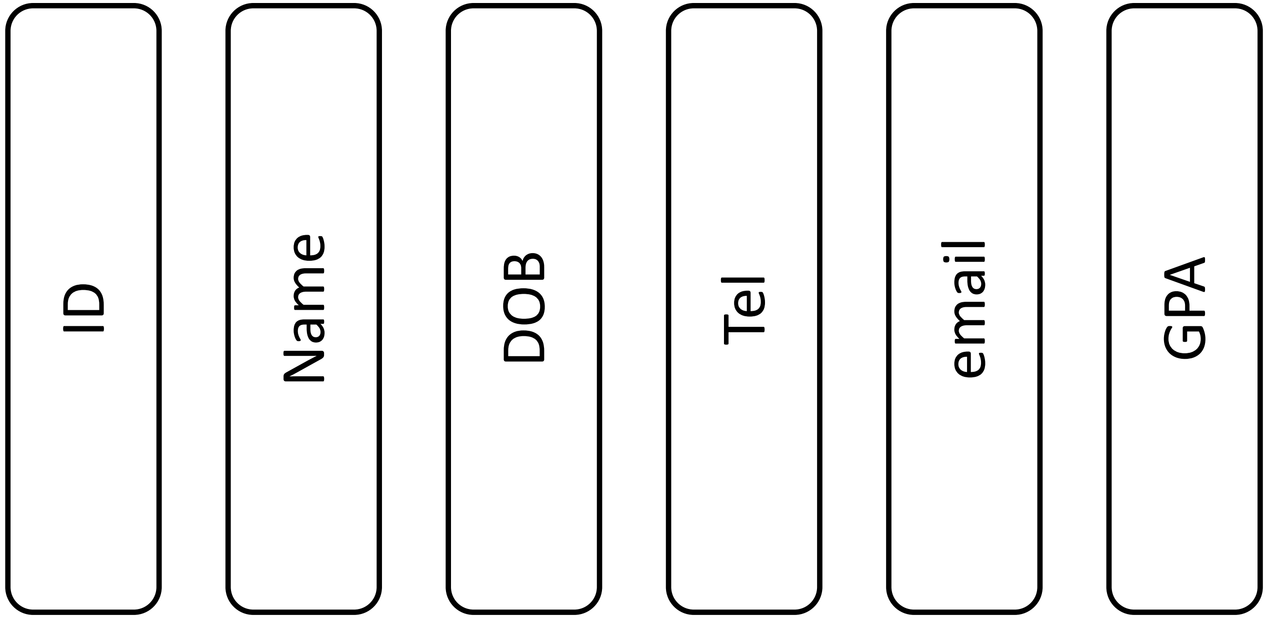
ID | Name | DOB | Tel | email | GPA

easy mapping from SQL to evaluation strategy

few basic operators: select, project, join, aggregate

simple logic for “query plan”

does that affect the way we ***evaluate*** queries?



ID

Name

DOB

Tel

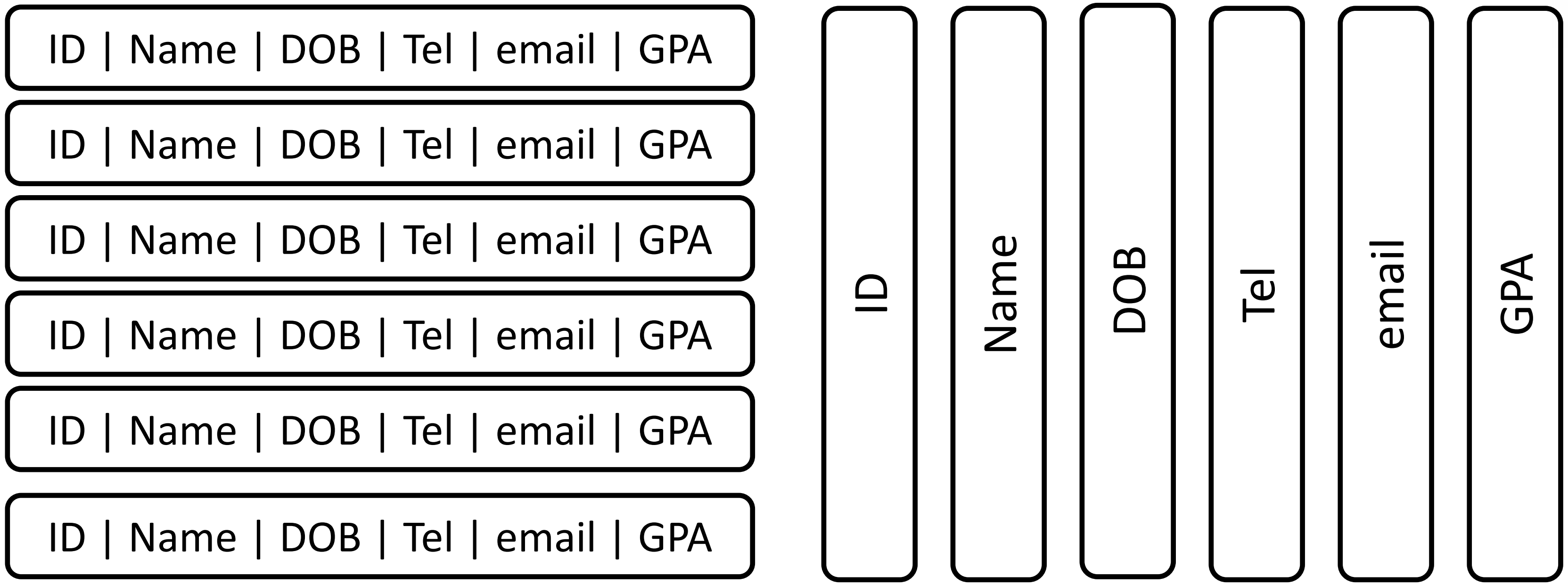
email

GPA

simpler basic operators

complicated query logic (more operators to connect)

does that affect the way we apply ***updates***?



ID | Name | DOB | Tel | email | GPA

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ID | Name | DOB | Tel | email | GPA

ID | Name | DOB | Tel | email | GPA

ID

Name

DOB

Tel

email

GPA

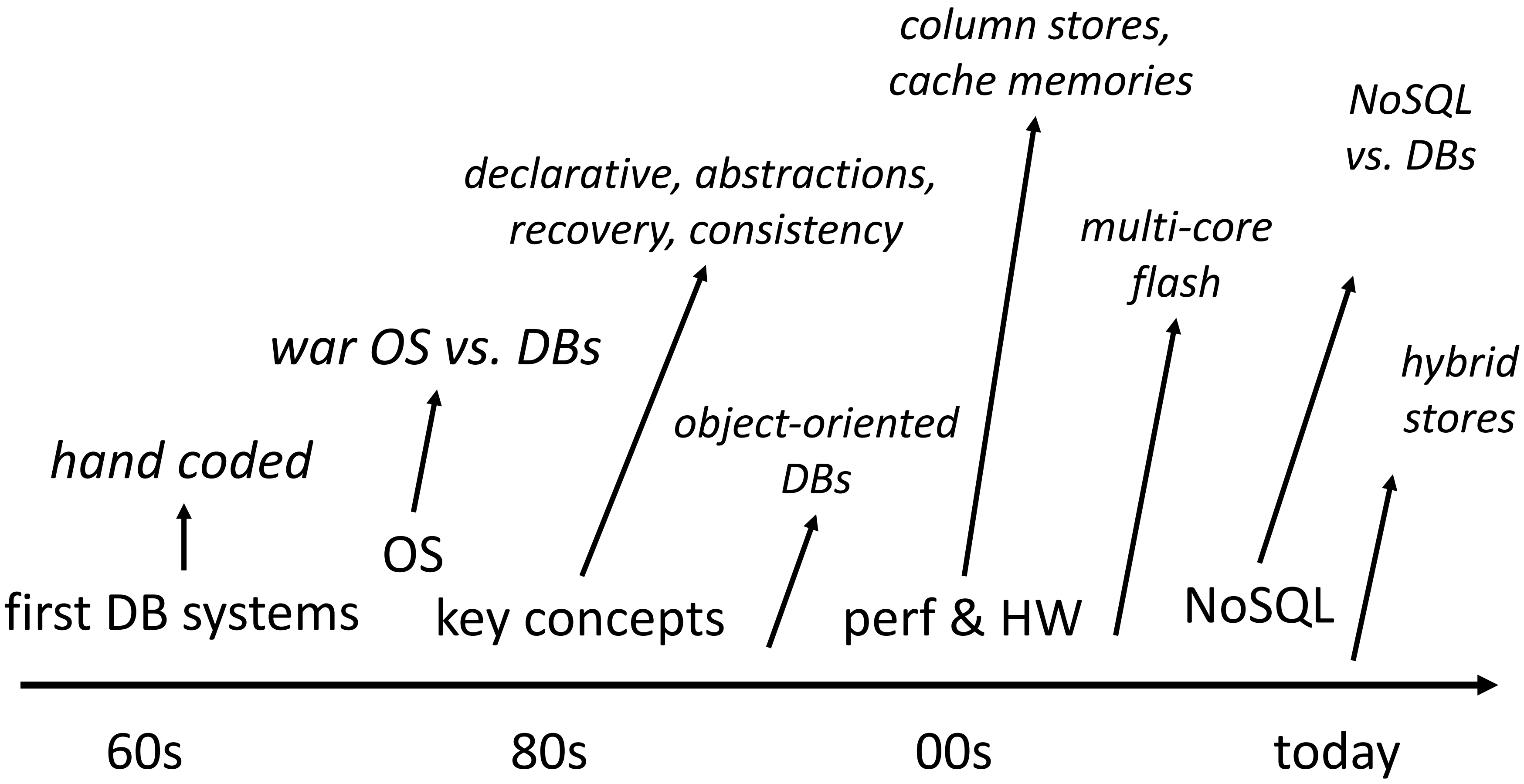
how to insert a new row?

how to delete a row?

how to change the GPA of a student?

how to update the email format of all students?

DBMS timeline



first DB systems → *hand coded*

OS → *war OS vs. DBs*

key concepts → *declarative, abstractions, recovery, consistency*

→ *object-oriented DBs*

perf & HW → *column stores, cache memories*

→ *multi-core flash*

NoSQL → *NoSQL vs. DBs*

→ *hybrid stores*

60s

80s

00s

today

Row-Stores vs. Column-Stores

physical data layout

simple query plan vs. simple operators

“transactions” vs. ”analytics”

Other Architectures?

Key-Value Stores (NoSQL)

no transactions

data model: **keys** & **values**

row: a key and an *arbitrarily complex* value

Graph Stores

natural representation of graph links

data model: **nodes** & **relationships**

also maybe: **weights, labels, properties**

Programming Assignment 1

take a **deep dive** in the internals of database systems

Using a templated system and detailed instructions

You will implement:

memory management modules

indexing & storage

query evaluation operators

First discussion was today in the lab

More Programming Assignments

rows vs. columns (compare the two main paradigms)

query optimization (understand the performance of a query)

key-value systems (deploy and use a KV-system)

Piazza

Announcements & Discussions in Piazza

https://piazza.com/bu/fall2020/cs460

Remember & Next Time

database systems: performance (energy, HW)

physical storage (row-oriented vs. col-oriented)
affects query engine/big design space

PA1: build a database system
More programming assignments on
(i) query optimization, (ii) row-stores vs. col-stores, (ii) key-value systems

Next: Modeling Data