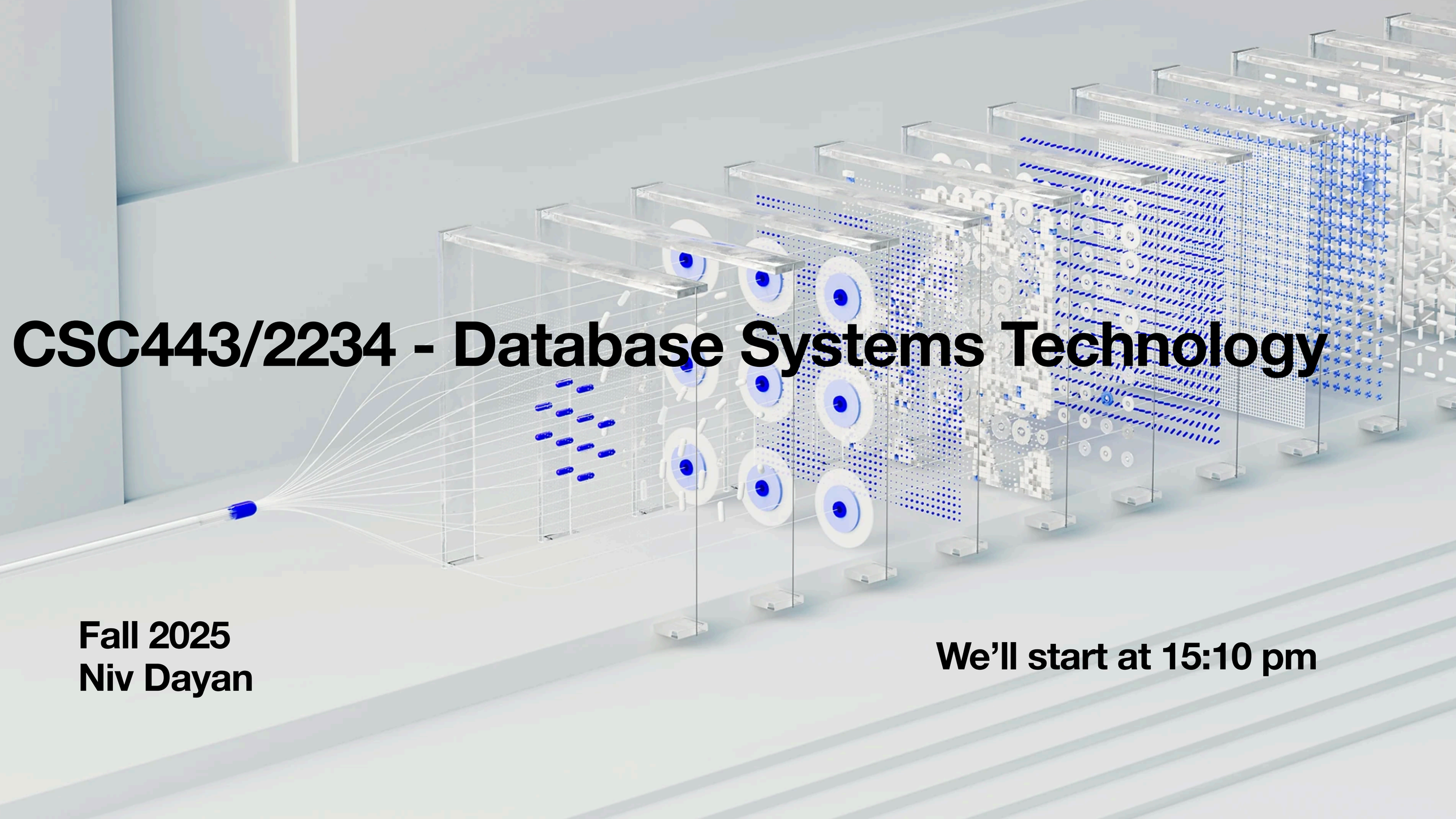


CSC443/2234 - Database Systems Technology

Fall 2025
Niv Dayan

We'll start at 15:10 pm

Who am I?

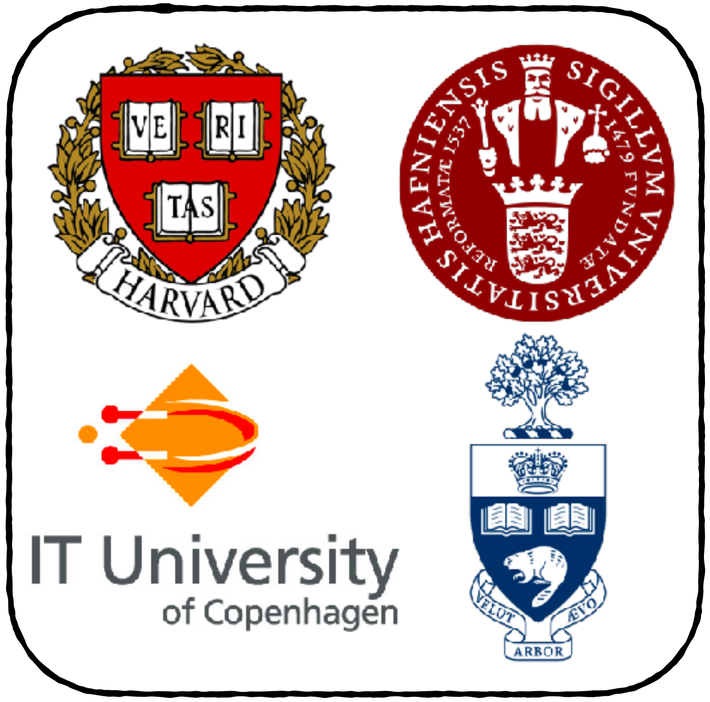
> 12 years of research experience in data structures & algorithms for databases

https://www.nivdayan.net/

Who am I?

> 10 years of research experience in data structures & algorithms for databases

In academia



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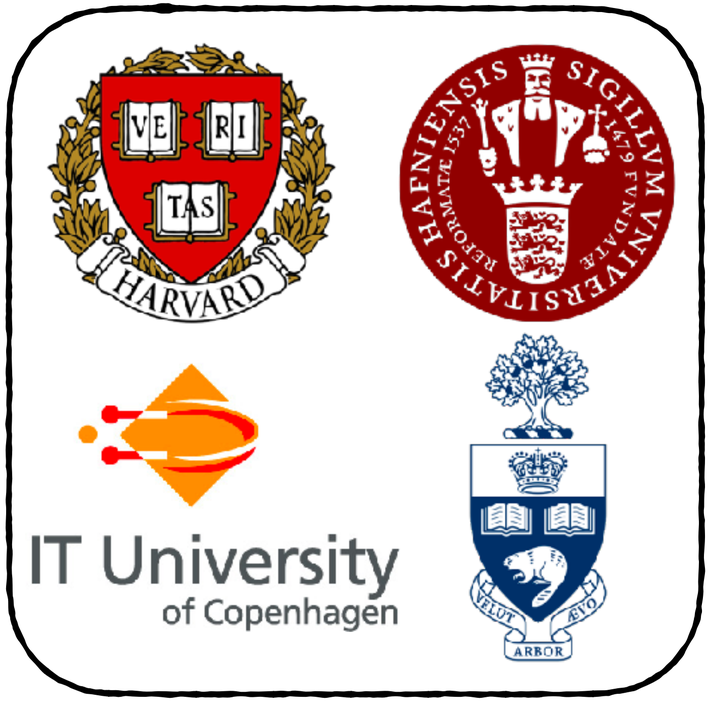
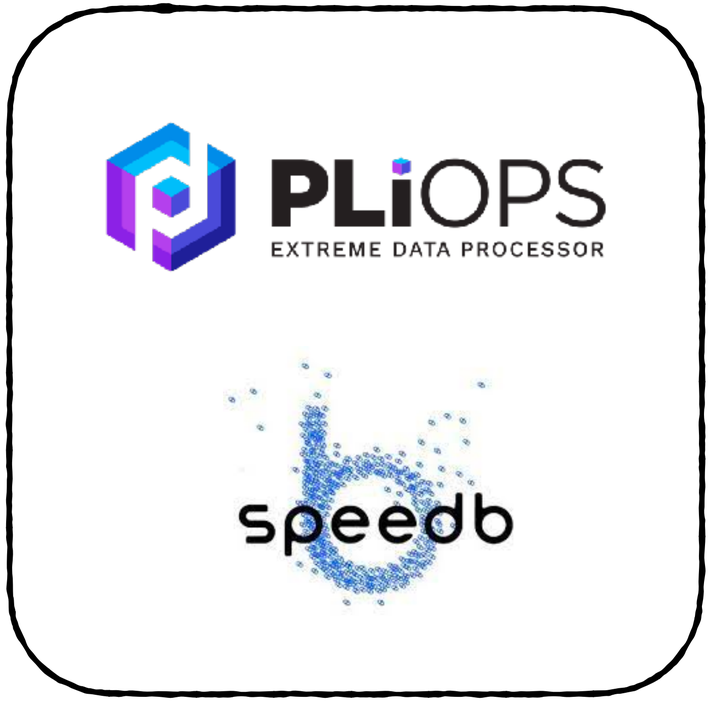


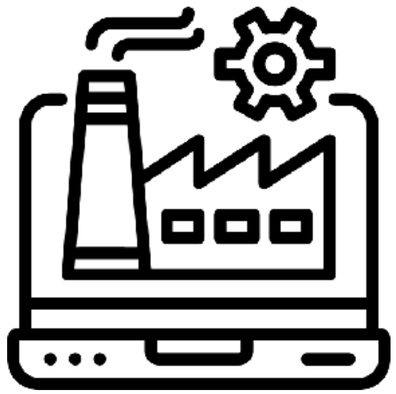
And in industry

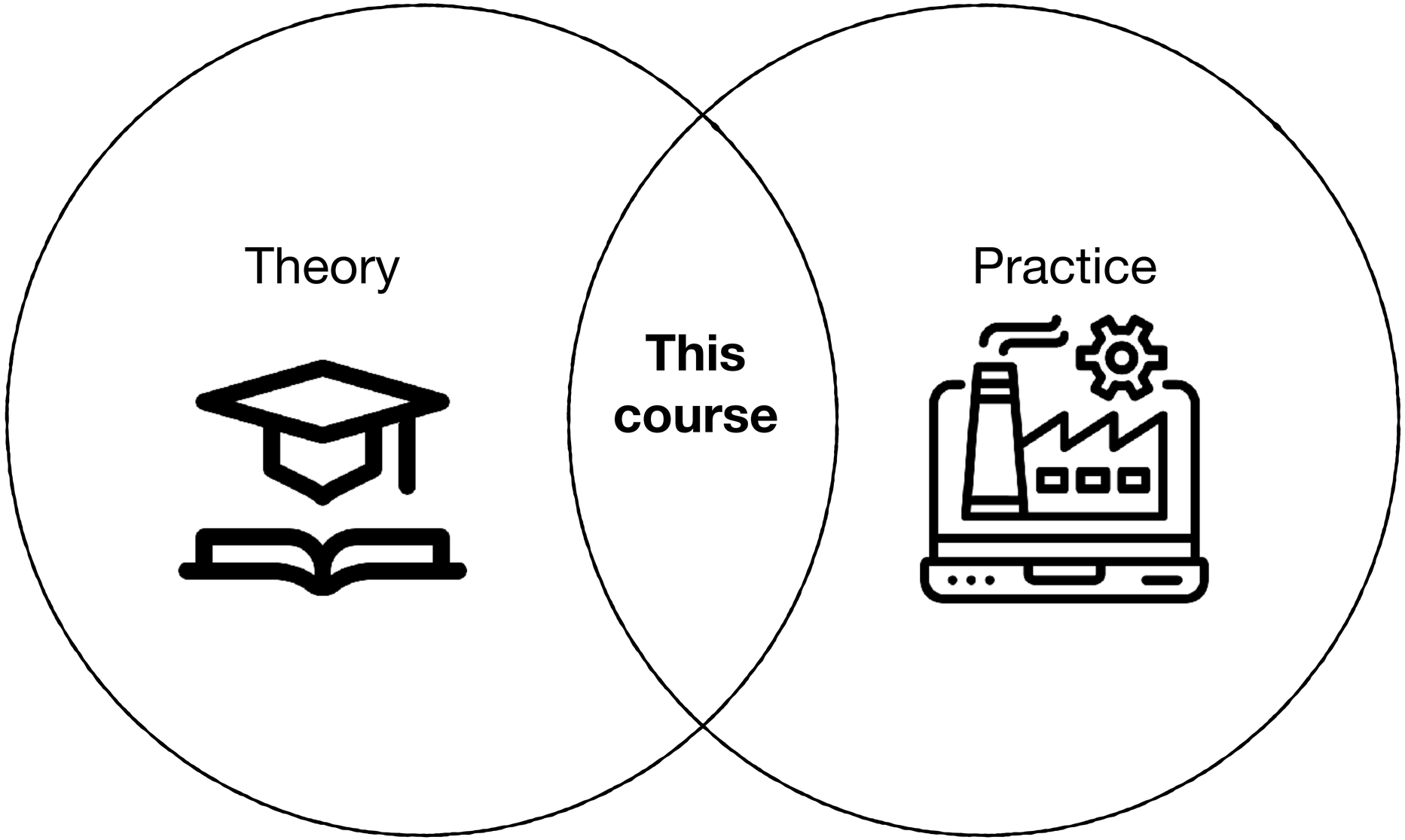


This course combines both

Theory

Practice




Theory
This course
Practice

Apologies for Absence the first 2 weeks!

Apologies for Absence the first 2 weeks!

Current Week

VLDB 2025

Apologies for Absence the first 2 weeks!

Current Week

VLDB 2025

Next Week

SYSTOR 2025

Apologies for Absence the first 2 weeks!

Current Week

VLDB 2025

Next Week

SYSTOR 2025

Returning to in-person the week after!

Apologies for Absence the first 2 weeks!

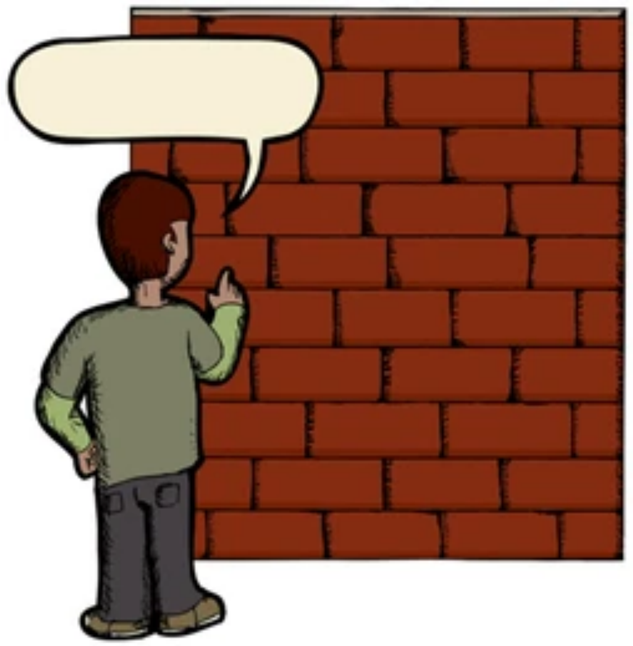
I don’t take missing class lightly

And class is usually quite fun!

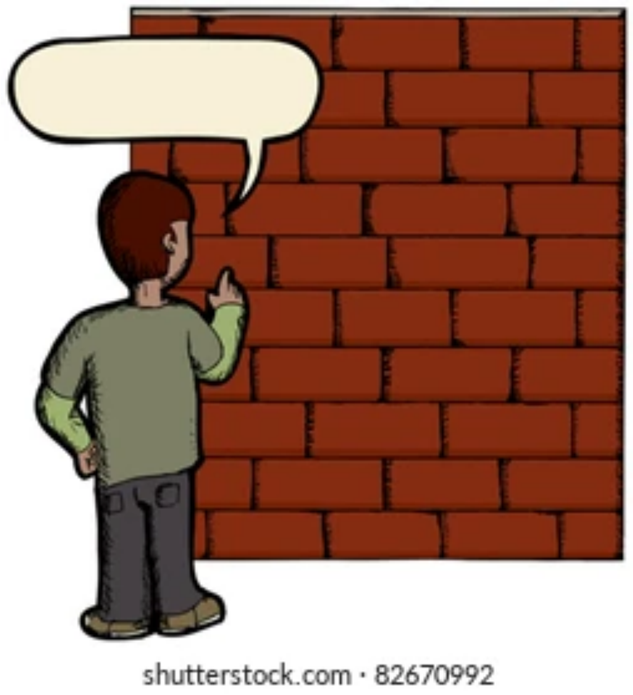
Apologies for Absence the first 2 weeks!

I was conferencing all day - so a little tired

A virtual class can feel like



A virtual class can feel like



Show your faces if you like it

Who are you? Prerequisites…

Who are you? Prerequisites…

Introduction to Databases

Relational algebra, data modeling, SQL

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Relational algebra, data modeling, SQL

Operating Systems

Concurrency & synchronization
File systems, virtual memory

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Design and Analysis of Data Structures

Binary trees, sorting, hash tables, priority queues, Big-O analysis

Who are you? Prerequisites…

Introduction to Databases

Relational algebra, data modeling, SQL

Operating Systems

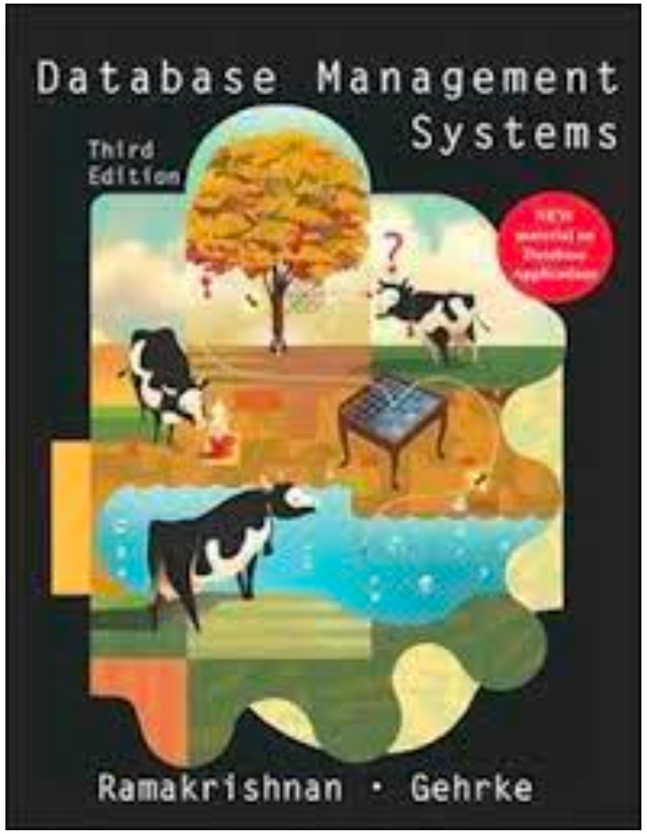
Concurrency & synchronization
File systems, virtual memory

Design and Analysis of Data Structures

Binary trees, sorting, hash tables, priority queues, Big-O analysis

Solid programming skills in C, C++, Java, or at least Python

Reading

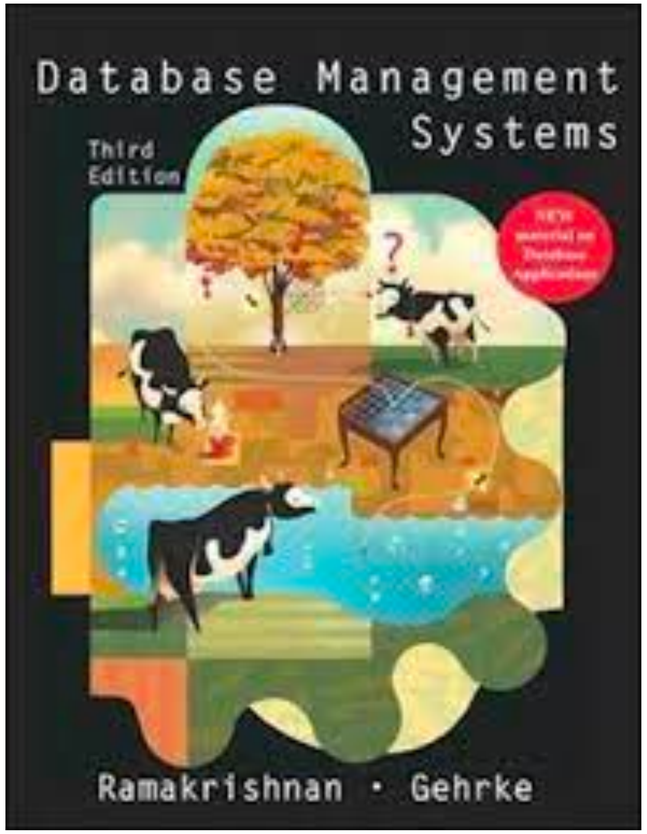


"Database Management Systems” 3rd Edition
Raghu Ramakrishnan & Johannes Gehrke

Classic, but dated (20 years old). A lot has changed

We’ll use it as a base, along with the slides and supplementary material to reflect 20 years of progress

Reading



Part 1 - Introduction	(Chapter 1)
Part 3 - Storage & Indexing	(Chapters 8-11)
Part 4 - Query Evaluation	(Chapters 12-15)
Part 5 - Transaction Management	(Chapters 16-18)

Check the course website for what to read each week

https://www.nivdayan.net/database-system-technology-csc443

Week 1: Introduction to the Course

Week 2: Storage Devices

Week 3: Table and Buffer Management

Week 4: Indexing with Hash Tables and B-Trees

Questions are always welcome!

Two-hour lectures can be long

Problem-based learning

Lectures are embedded with thinking exercises

Please participate!

Post questions for everyone’s benefit!

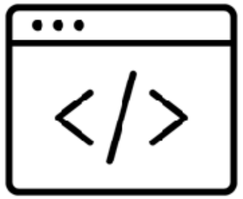
Available but there may be hiccups so please come to class

Group Project

Mini-database system

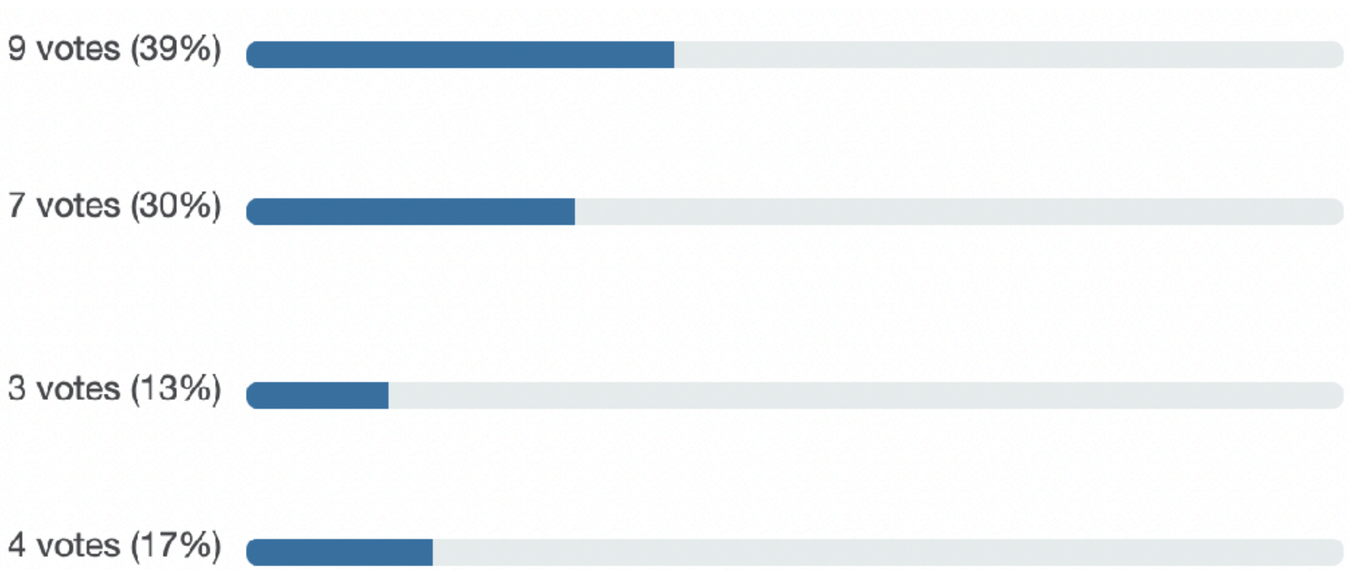
More later

C++



Groups of _

Group Experiences (winter 2023)



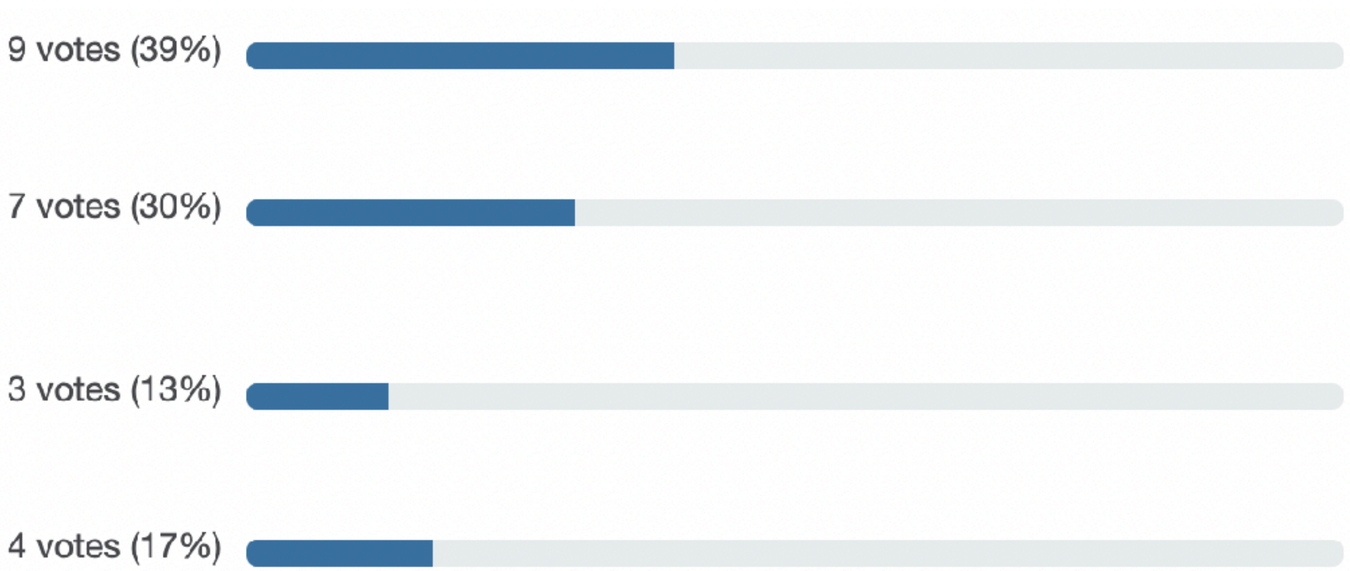
My team functioned great, distributed the work fairly, and I made new friends or strengthened existing friendships

My team functioned ok, though there were some problems. At the same time, I am happy this was a group project, and I picked up better skills for working in teams in the future.

My team didn't function so well, and team dynamics were stressful. At the same time, we still somehow pulled through. I am not sure if the experience was worthwhile.

Working as a group was disastrous, and I wish the project could have been done single-handedly

Group Experiences (winter 2023)



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Working as a group was disastrous, and I wish the project could have been done single-handedly

We'll try making this a smoother experience for everyone

Marking Scheme

Project (40%)

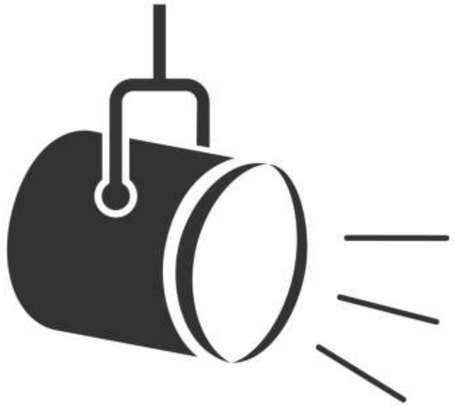
Midterm (20%)

Final (40%)

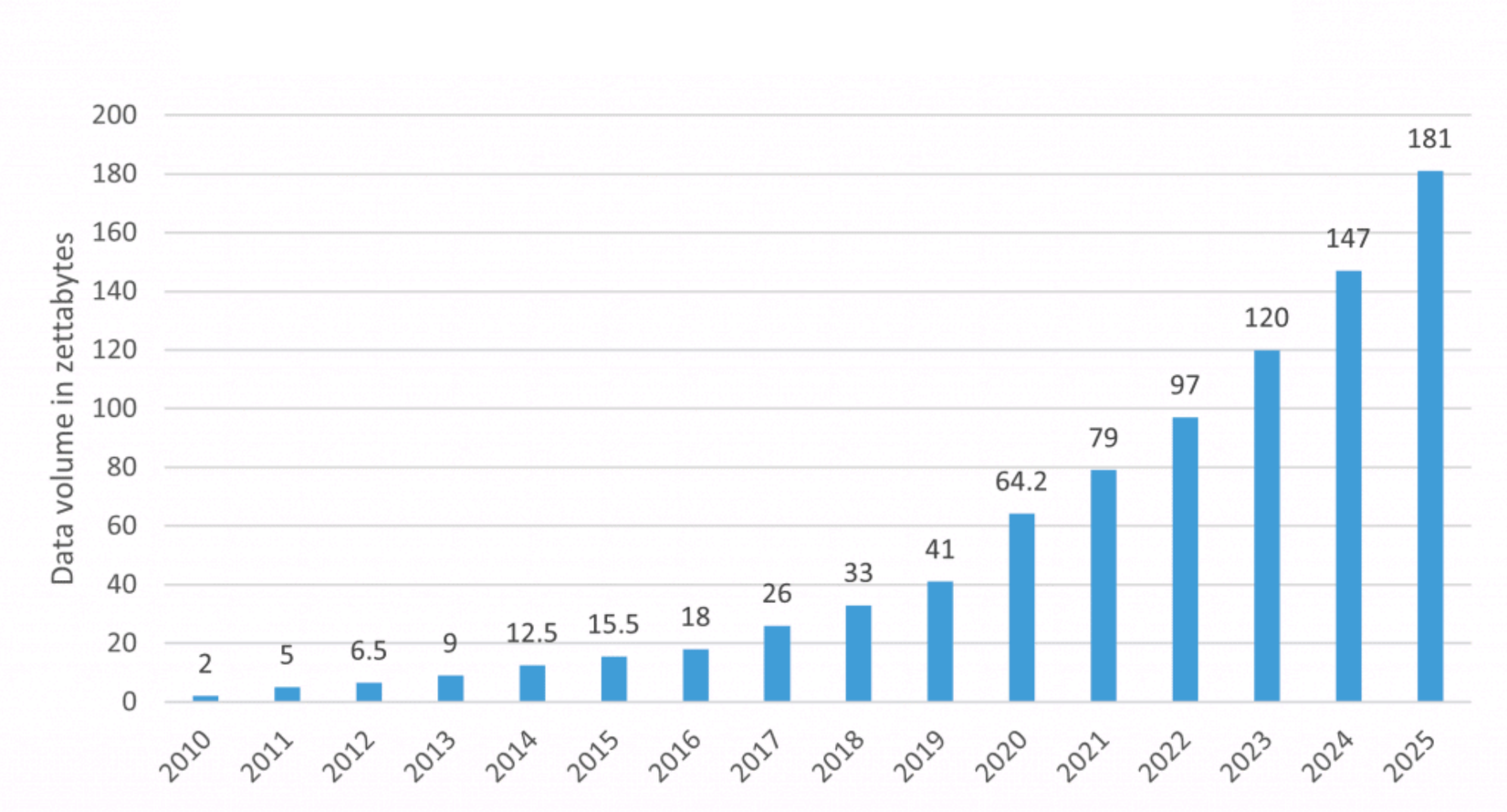
Tutorials are Exam Prep

Research Problems to push your understanding

Course introduction



Every 2 years, the amount of data humanity produces doubles



	# bytes
Zettabytes	2^{70}
Exabytes	2^{60}
Petabytes	2^{50}
Terabytes	2^{40}
Gigabytes	2^{30}
Megabytes	2^{20}
Kilobytes	2^{10}

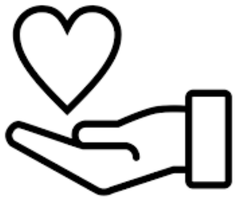
This data is…

stored by data management systems.

This data is…

stored by data management systems.

used everywhere
(business, science, NGOs, etc)



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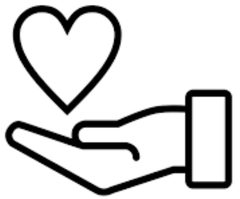

You will likely work with data, no matter where you go

Big Data

Admittedly, a buzzword

Big Data

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Refers to growth of data beyond our ability to curate and derive meaning from it. Since early 2000’s.

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"One size does not fit all."

A (rough) timeline

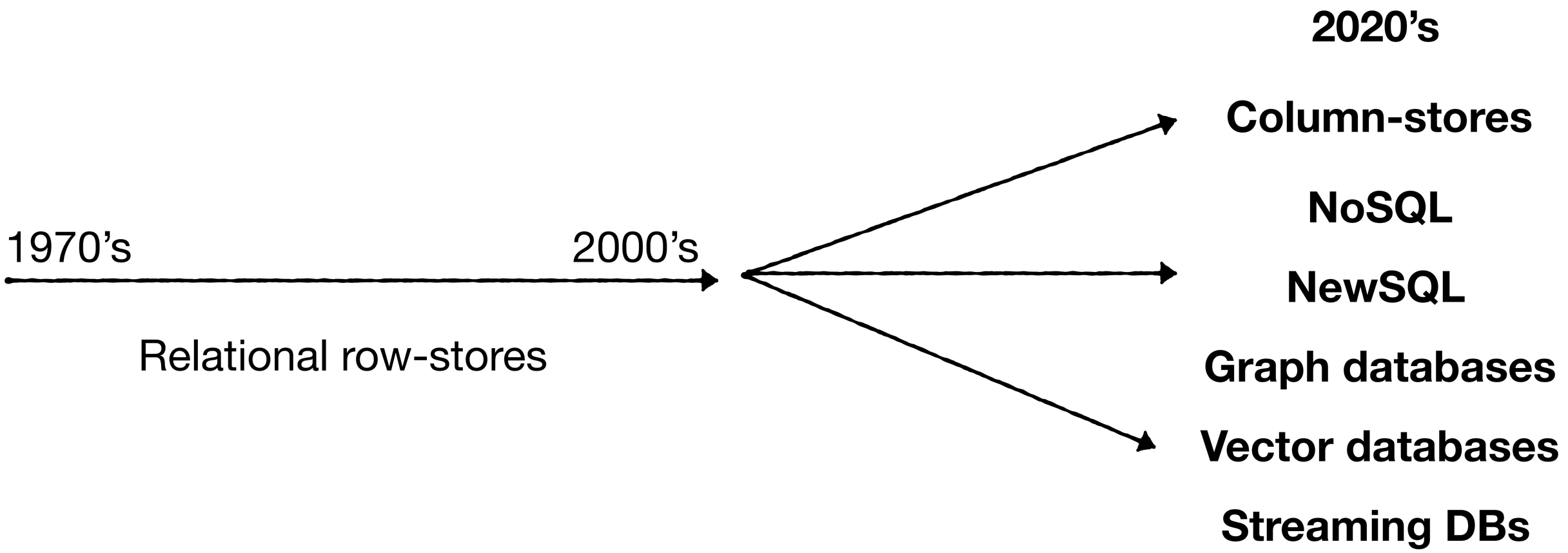
Relational row-stores

A (rough) timeline

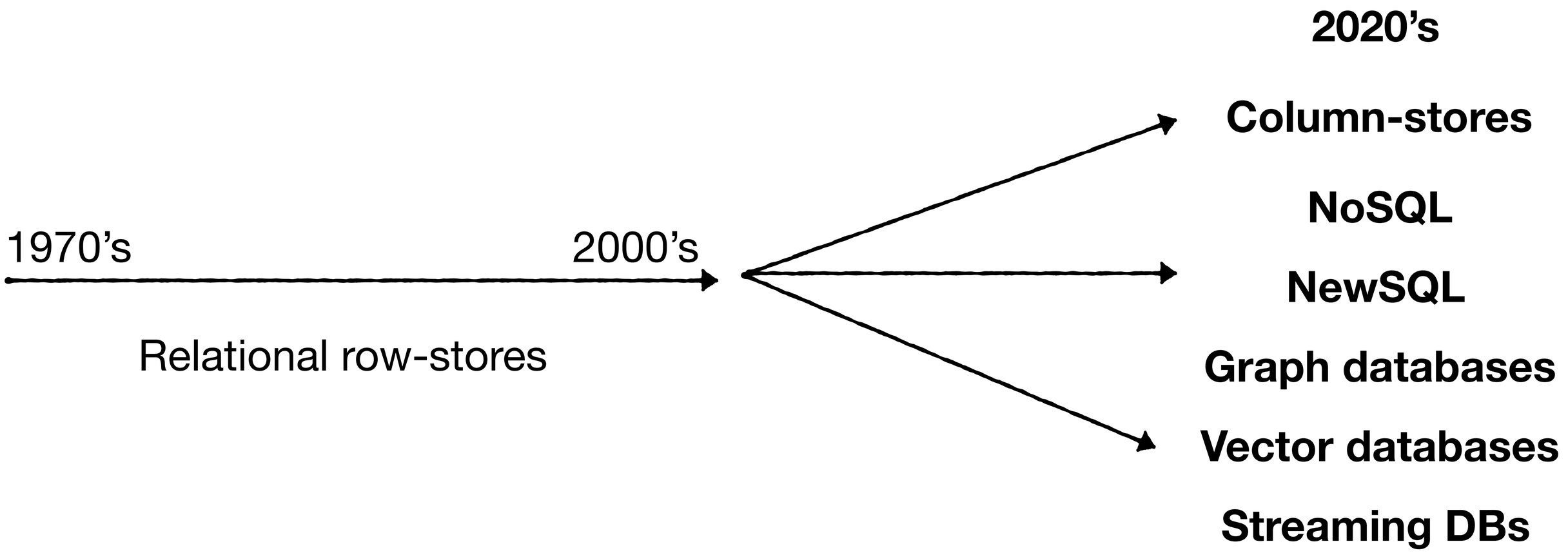
1970’s 2000’s

Relational row-stores

A (rough) timeline



A (rough) timeline

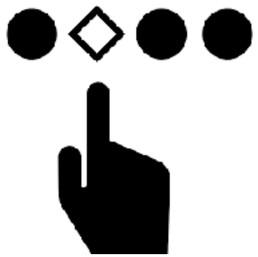


We can’t cover all of them, but we’ll give you basic design principles underpinning them all.

What will this course help you with?

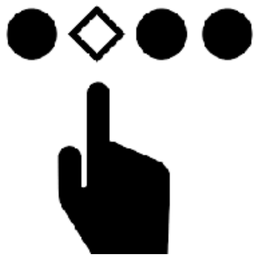
What will this course help you with?

Choose



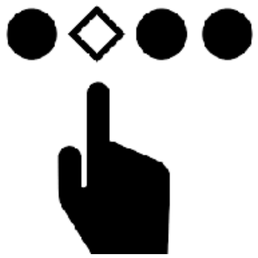
How to choose a database for a particular use-case.

Choose **Use**



Model, index & query the data with performance in mind

Choose

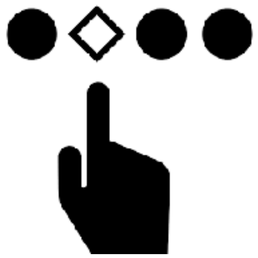


Use

Tune

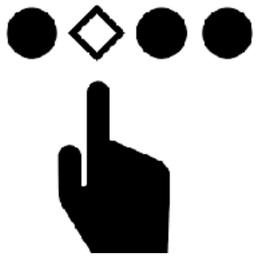
Tune parameters to improve performance

Choose Use Tune **Extend**



Add functionality and improved algorithms

Choose



Use

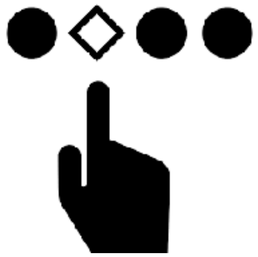
Tune

Extend

Build

Build new databases for new use-cases
(ML, self-driving cars, VR, etc)

Choose



Use

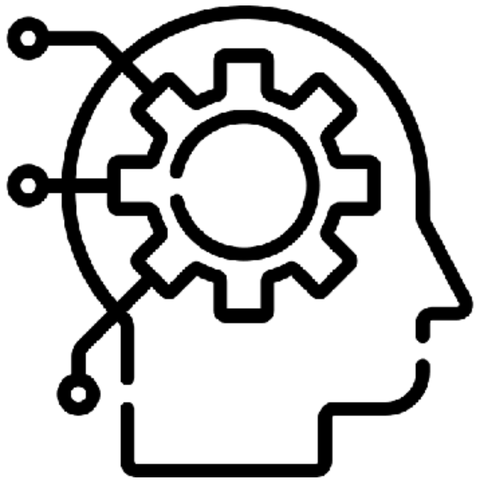
Tune

Extend

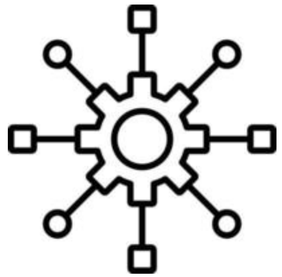
Build

These all require deep knowledge of database anatomy

Themes & learning outcomes

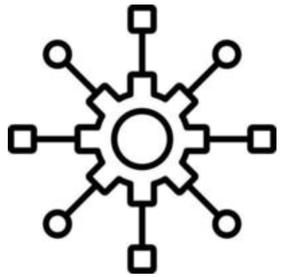


Algorithms & data structures

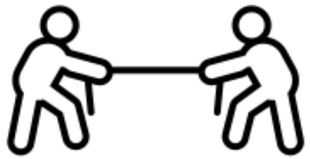


The nuts and bolts of every database system

Algorithms &
data structures

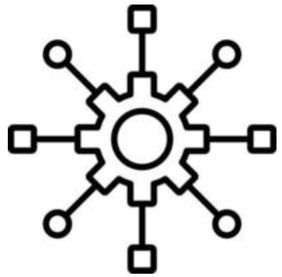


Trade-offs



There is usually many design options with different trade-offs.

Algorithms &
data structures



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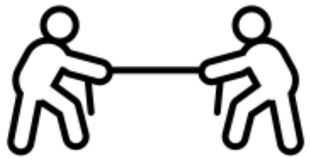
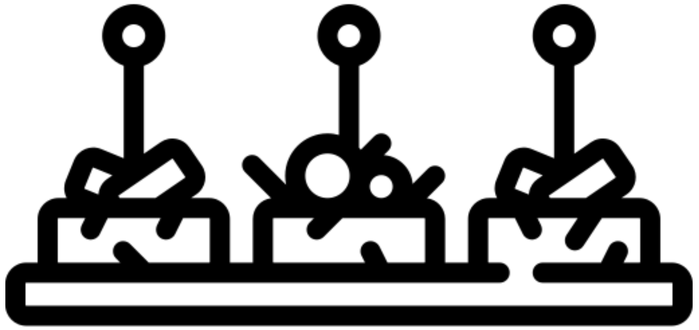


Performance

Do more with less

Appetizers Menu



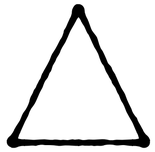
Appetizers Menu

Storage

Tables

Buffer Management

Indexes



Sorting

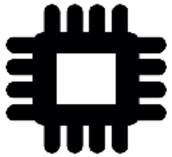
Operators

Query Optimization

Transactions

Recovery

Storage



CPU caches

memory

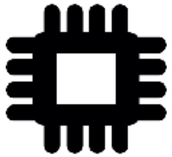
SSD

disk

Expensive & fast

Slow & cheap

Storage



CPU caches

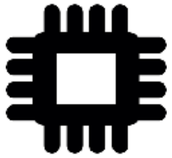
memory

SSD

disk

Optimize data movement

Storage



CPU caches

memory

SSD

disk

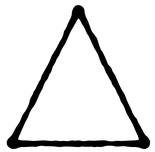
The architecture of modern DBs emerges from the properties of the memory hierarchy

Storage

Tables

Buffer Management

Indexes



Sorting

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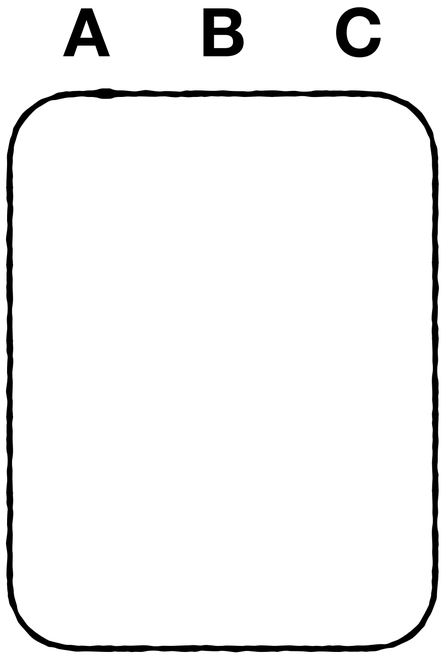
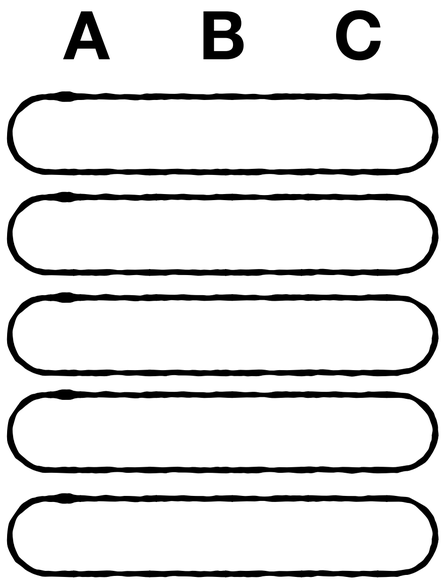
Tables

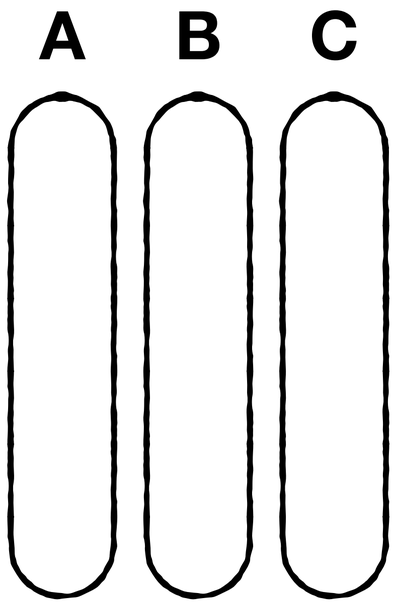


efficient inserts, updates, deletes & scans?

Tables



Row-Stores



Column-Stores

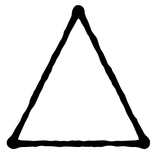
Structuring tables to optimize for different types of queries

Storage

Tables

Buffer Management

Indexes



Sorting

Operators

Query Optimization

Transactions

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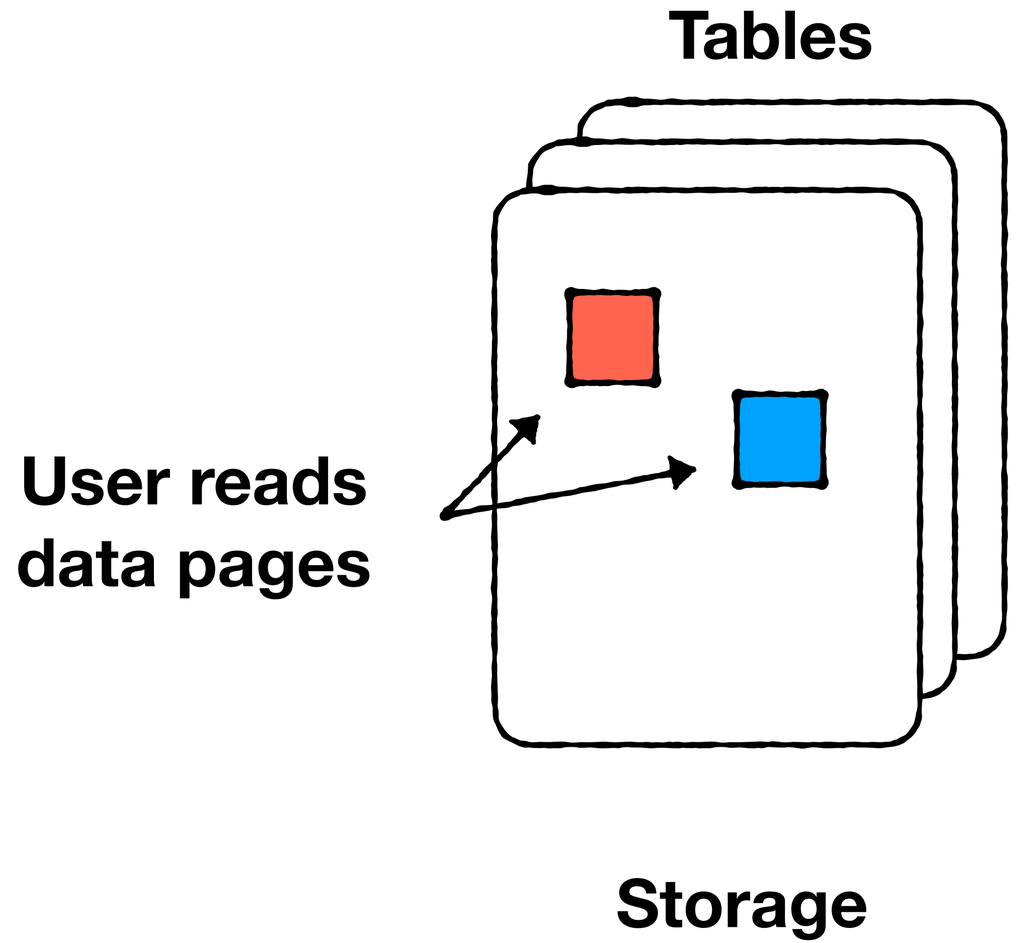
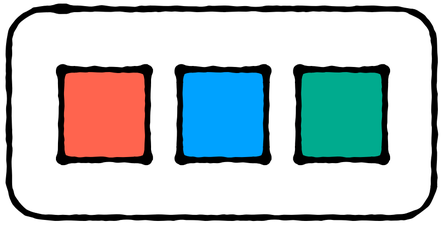
Buffer Management

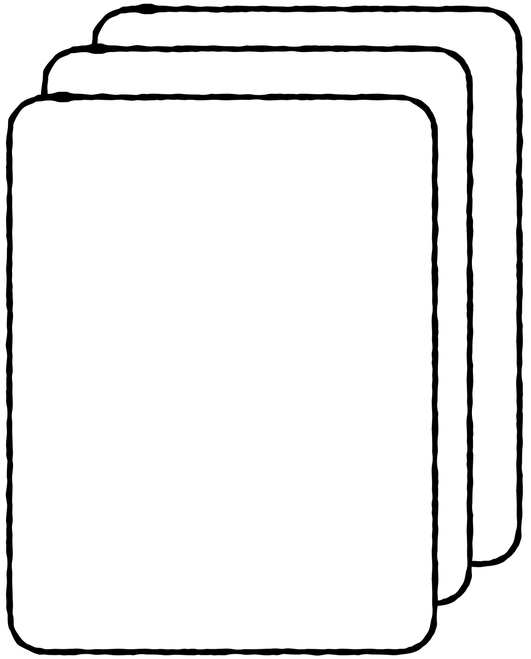


Buffer Management

Buffer Pool



Tables

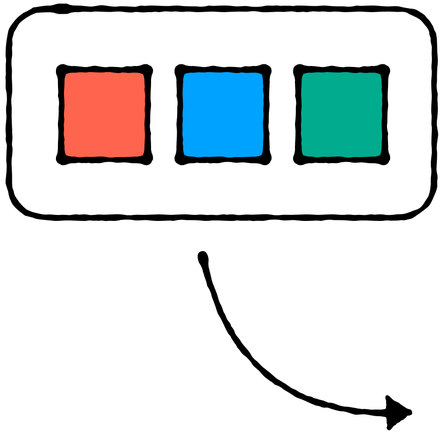


Memory

Storage

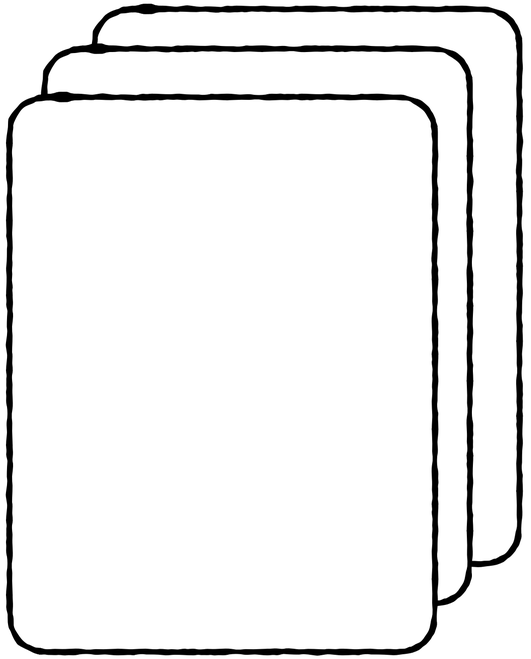
Buffer Management

Buffer Pool



Which page to evict when we run out of space?

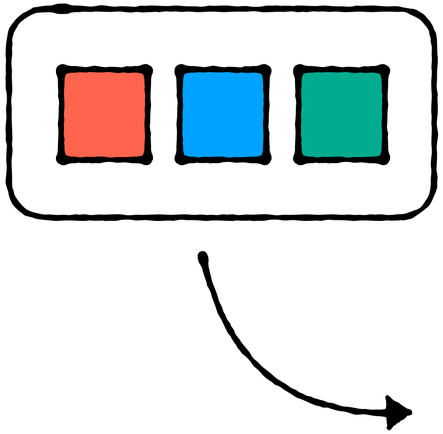
Tables



Storage

Buffer Management

Buffer Pool

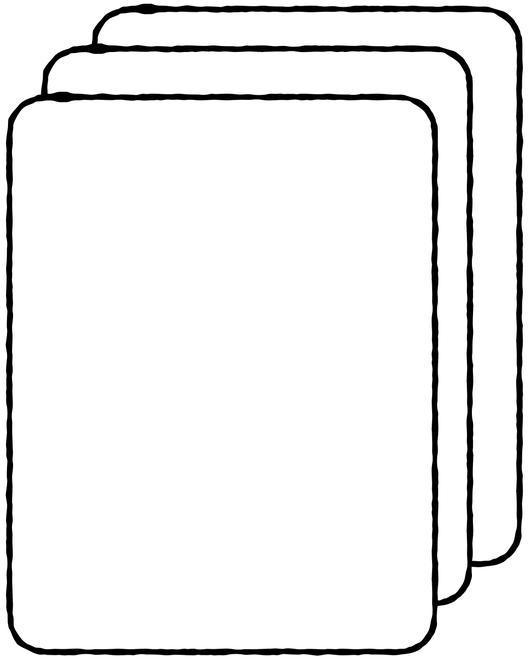


Which page to evict when
we run out of space?

Random, FIFO, LRU, MRU, Clock

Different trade-offs

Tables



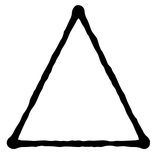
Storage

Storage

Tables

Buffer Management

Indexes



Sorting

Operators

Query Optimization

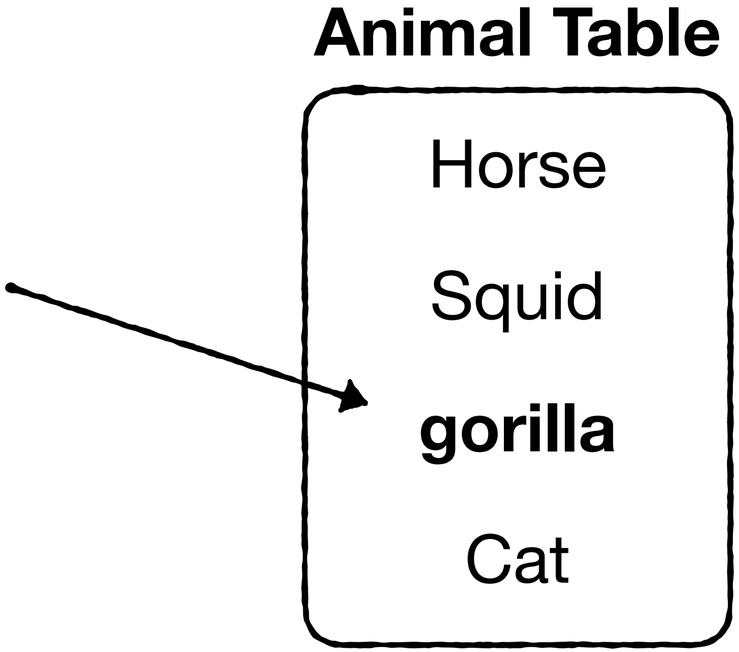
Transactions

Recovery

Indexes

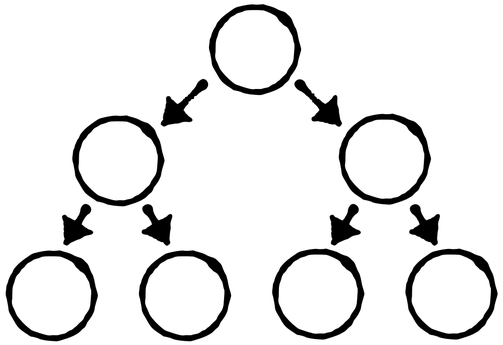
Select * from animals where name = “**gorilla**”

How to find quickly without a full scan?

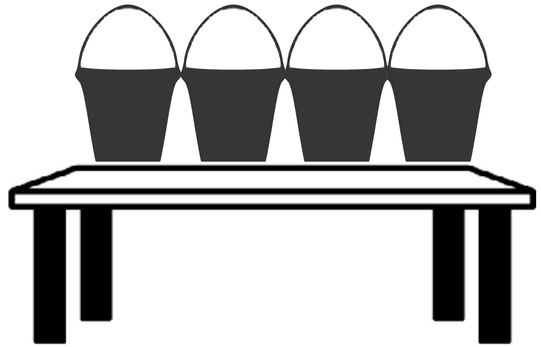


Indexes

You have learned about



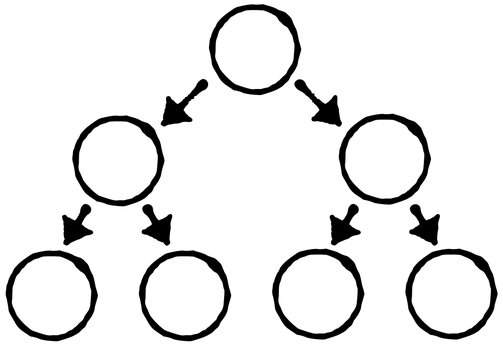
Binary trees



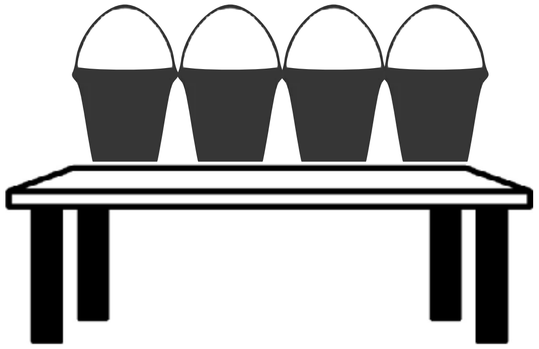
Hash tables

Indexes

You have learned about



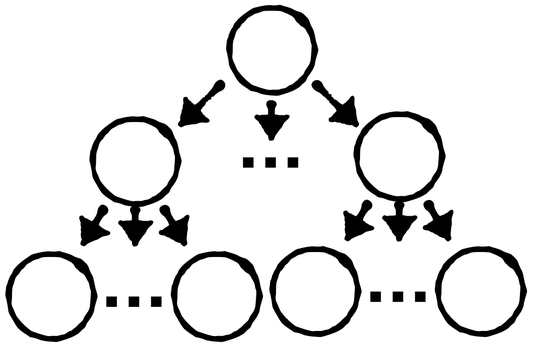
Binary trees



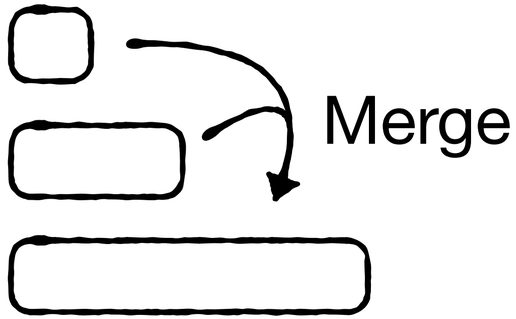
Hash tables

Not a good fit for disks or SSDs

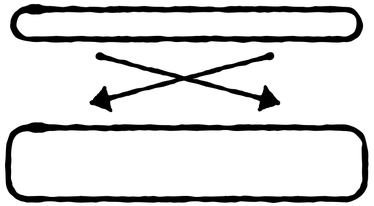
Indexes



B-Trees

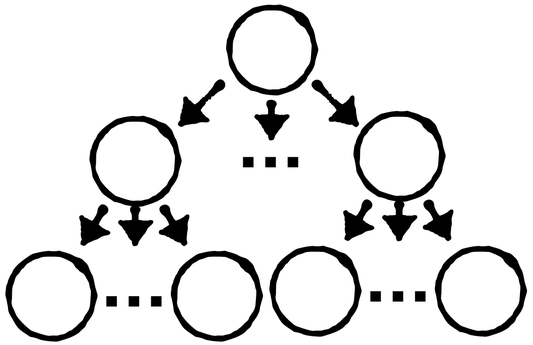


Log-Structured Merge-Trees

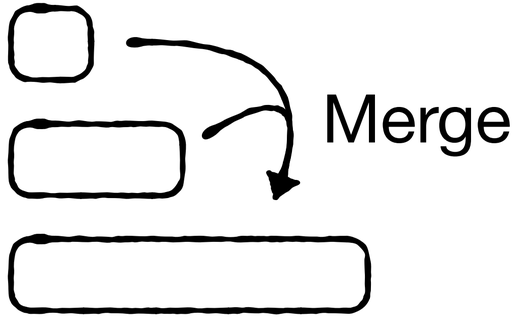


Circular Log

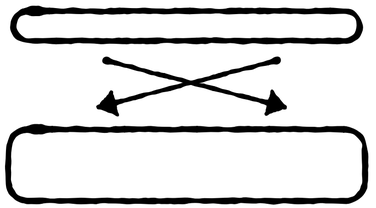
Indexes



B-Trees



Log-Structured
Merge-Trees



Circular Log

Cheaper queries

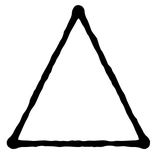
More memory
Cheaper writes

Storage

Tables

Buffer Management

Indexes



Sorting

Operators

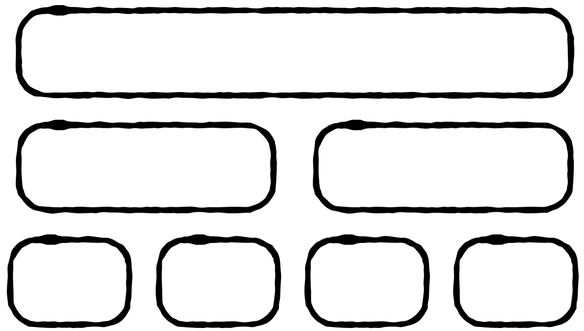
Query Optimization

Transactions

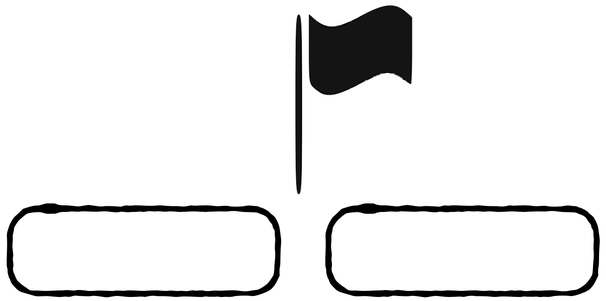
Recovery

Sorting

You have learned about



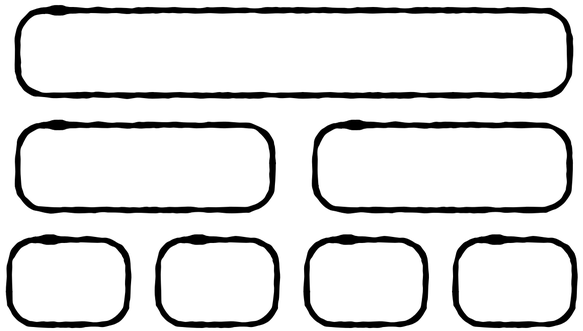
Merge-Sort



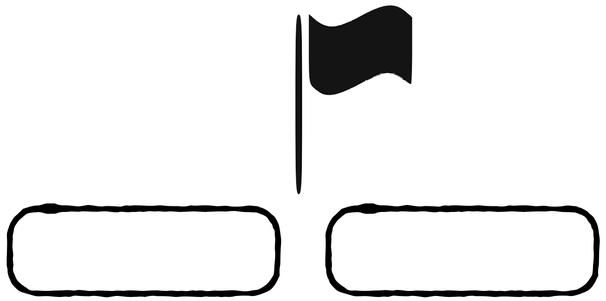
Quick-Sort

Sorting

You have learned about



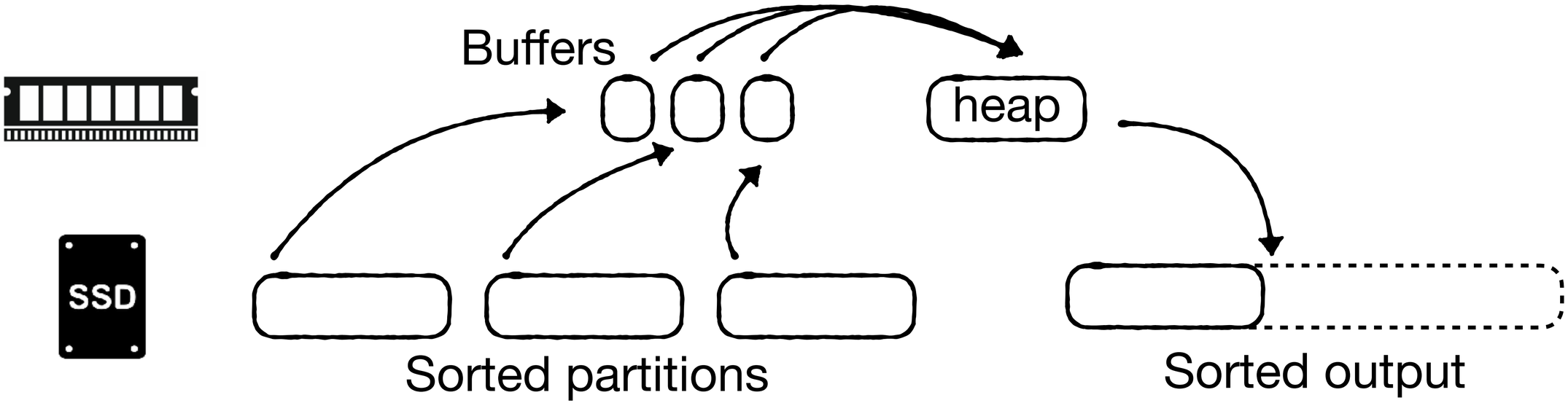
Merge-Sort



Quick-Sort

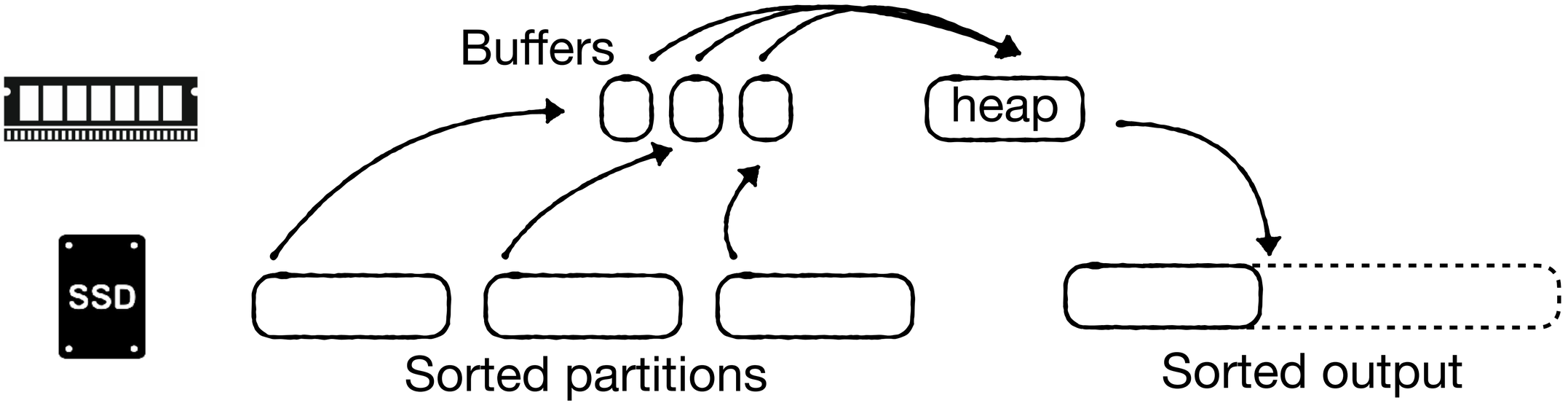
Also not a good fit for disks or SSDs

Sorting



Multi-way merge-sort

Sorting



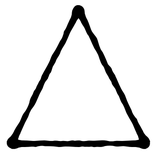
Sorts massive amounts of data in storage efficiently!

Storage

Tables

Buffer Management

Indexes



Sorting

Operators

Query Optimization

Transactions

Recovery

Relational Operators: The algorithms used to physically answer queries

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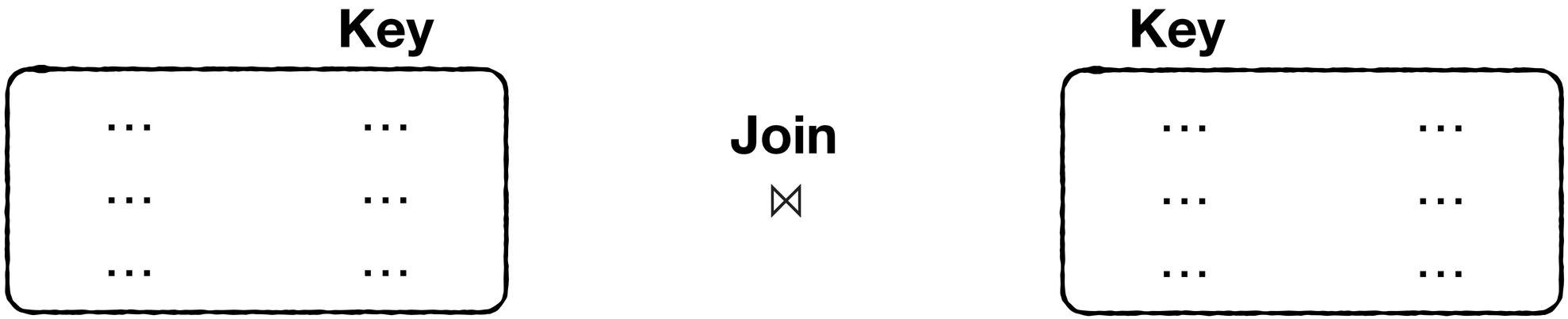
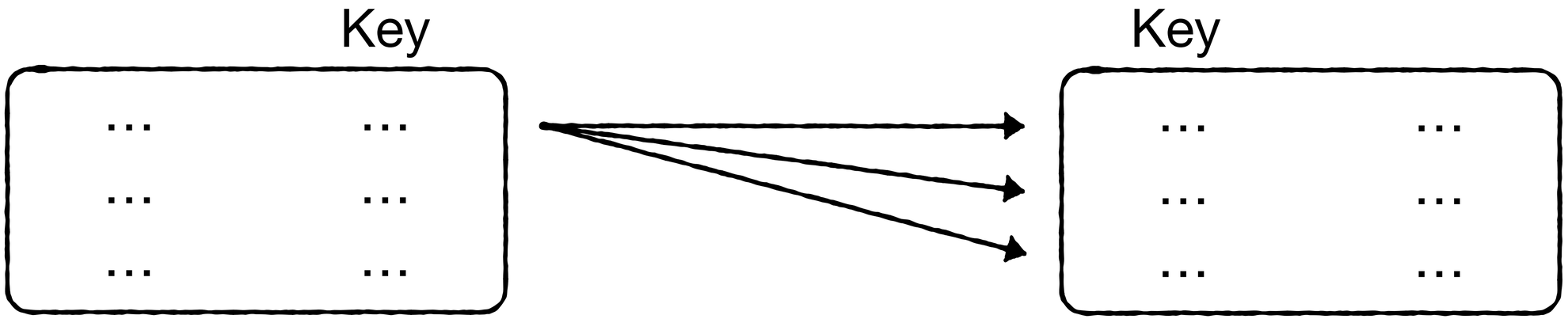
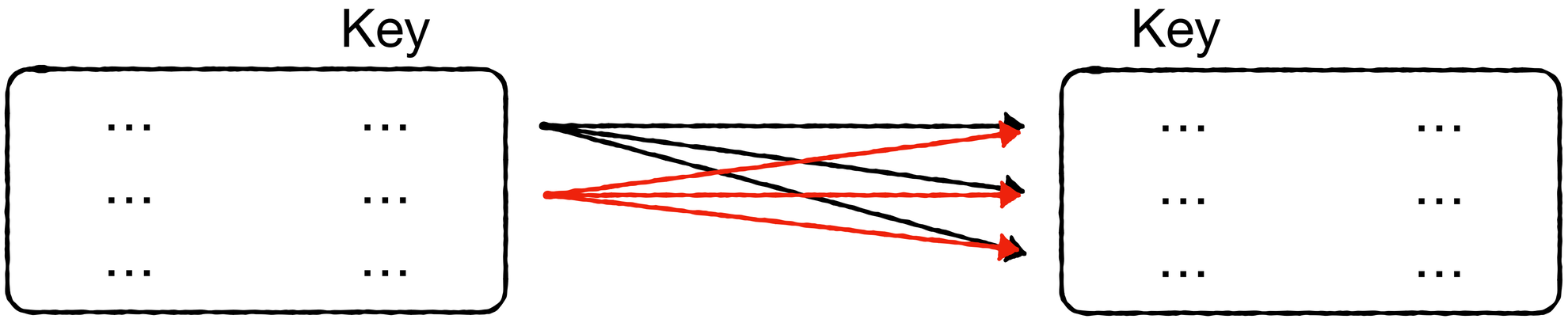


Relational Operators: The algorithms used to physically answer queries



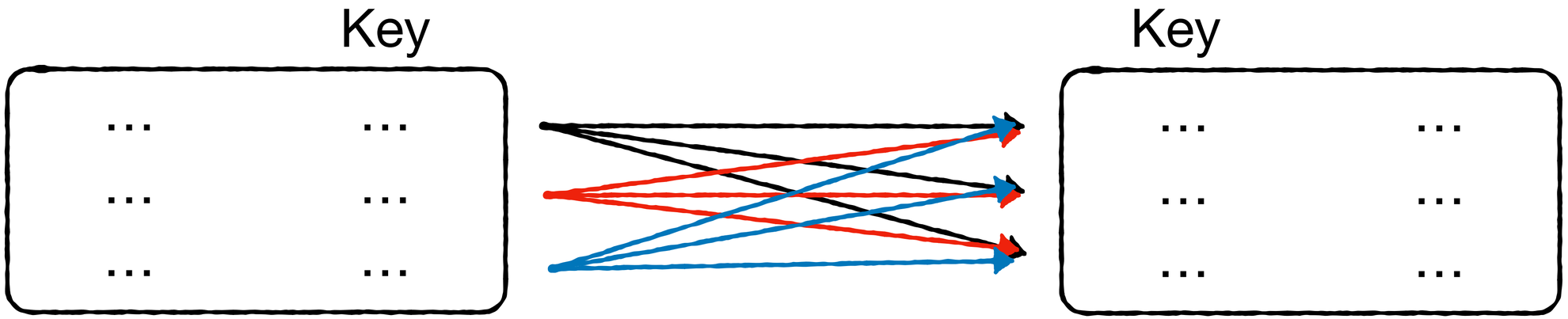
Nested join?

Relational Operators: The algorithms used to physically answer queries



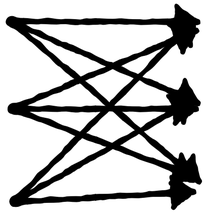
Nested join

Relational Operators: The algorithms used to physically answer queries

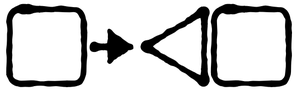


Nested join

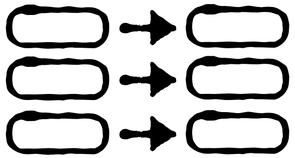
Relational Operators: The algorithms used to physically answer queries



Nested join



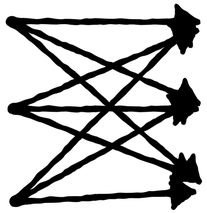
Index join



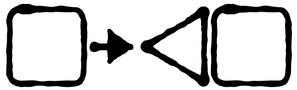
Grace Hash join

etc…

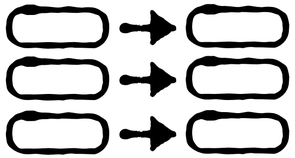
Relational Operators: The algorithms used to physically answer queries



Nested join



Index join



Grace Hash join

etc…

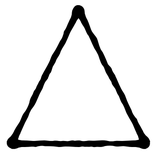
All have different properties and trade-offs :)

Storage

Tables

Buffer Management

Indexes



Sorting

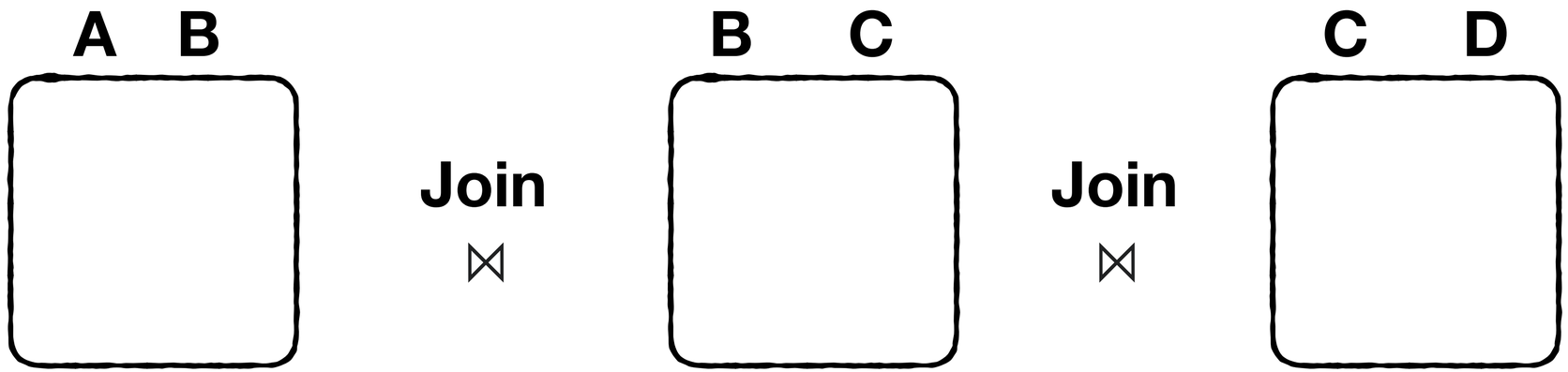
Operators

Query Optimization

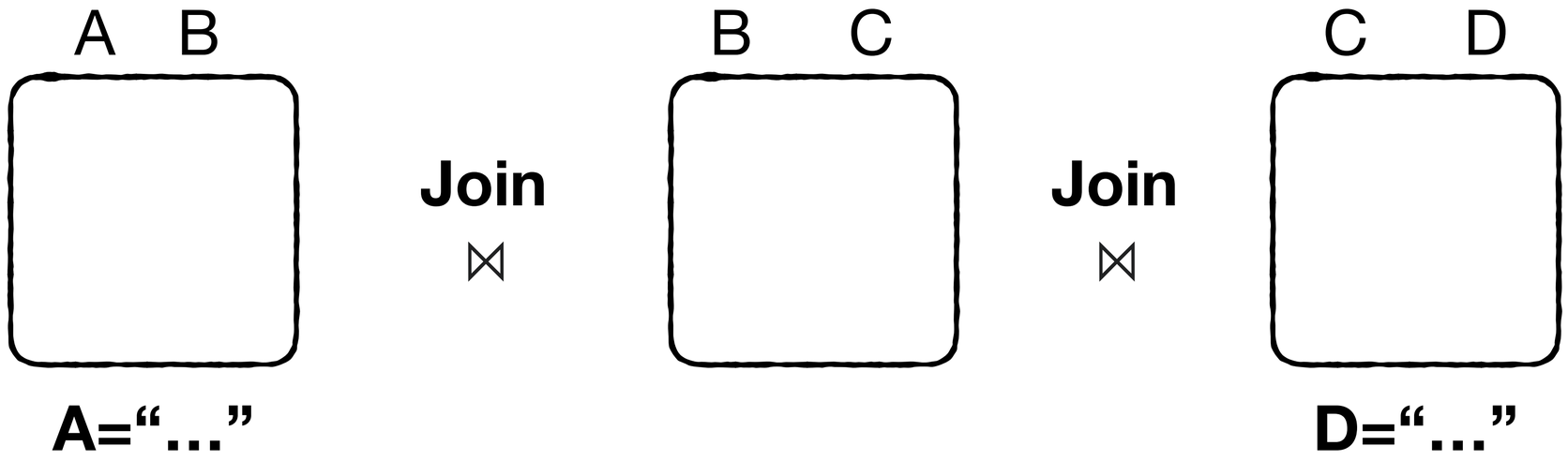
Transactions

Recovery

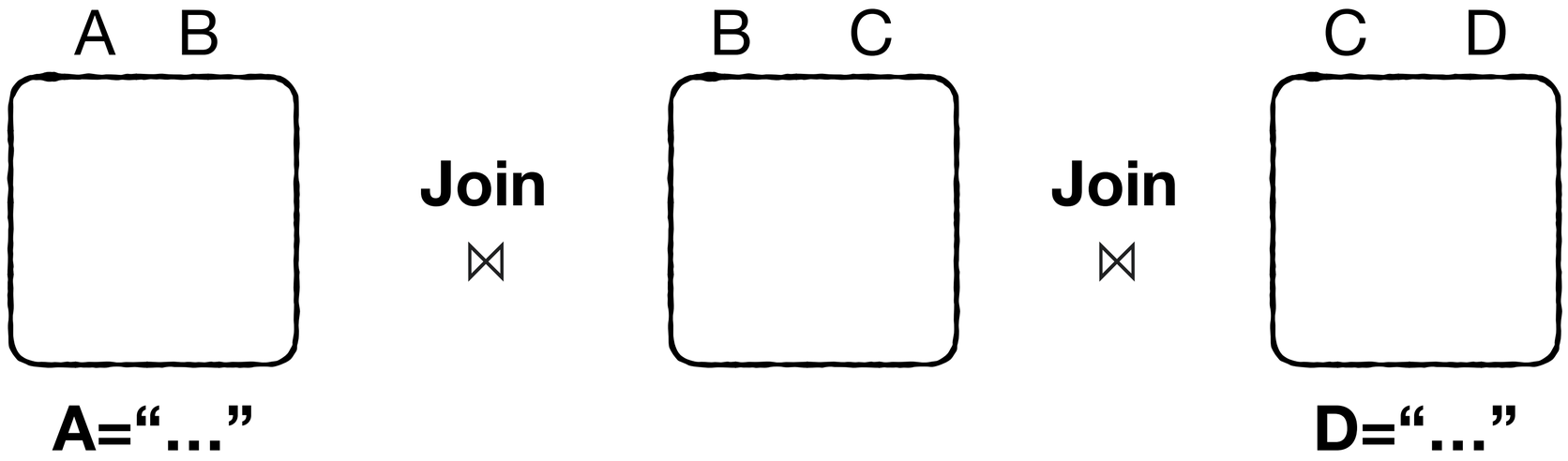
Query Optimization: constructing efficient query plans



Query Optimization: constructing efficient query plans

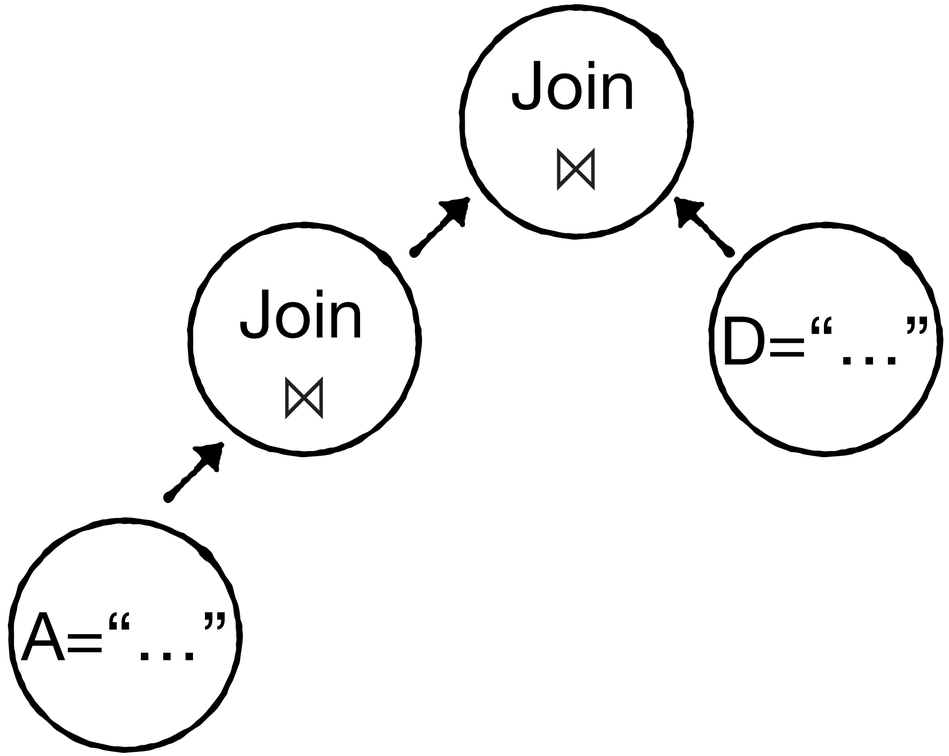


Query Optimization: constructing efficient query plans

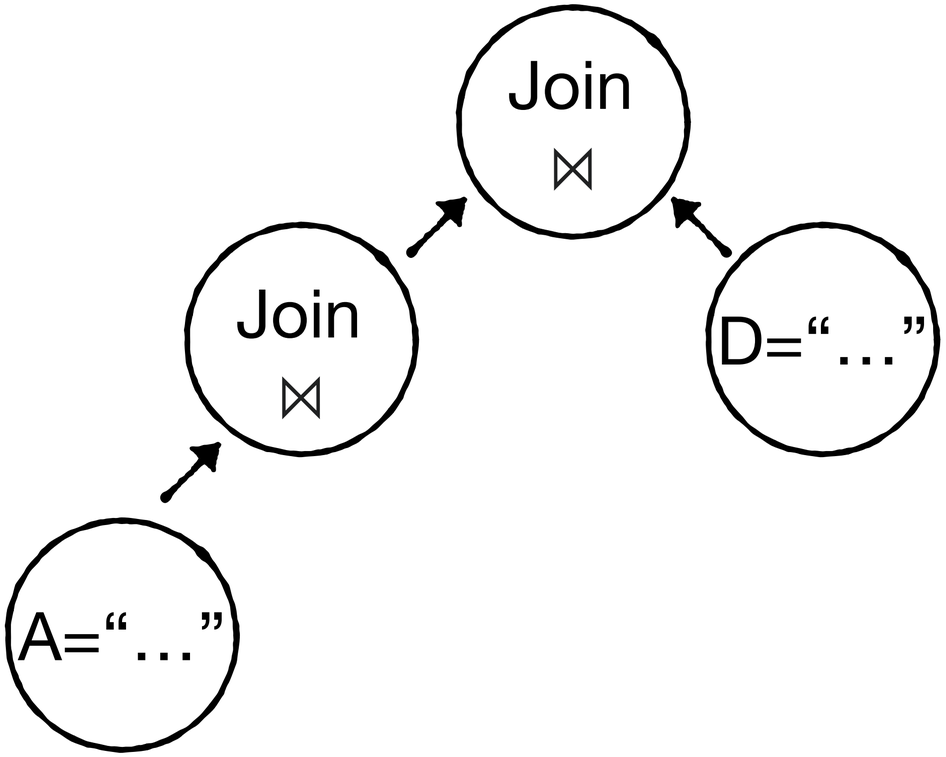


In which order to perform these operations?

Query Optimization: constructing efficient query plans



Query Optimization: constructing efficient query plans



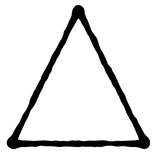
Using statistics & heuristics

Storage

Tables

Buffer Management

Indexes



Sorting

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Query Optimization

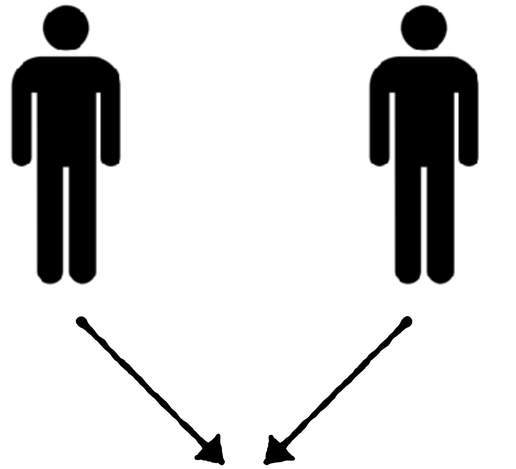
Transactions

Recovery

Transactions: ensuring complex operations run correctly, concurrently, and with fail-safety

Transactions: ensuring complex operations run correctly, concurrently, and with fail-safety

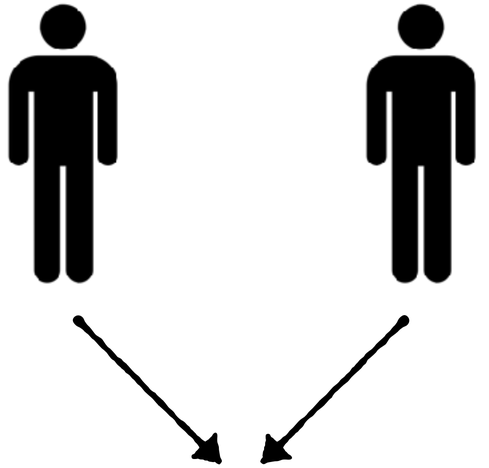
Two customers paying to an account at the same time can overwrite each other's changes



Account balance

Transactions: ensuring complex operations run correctly, concurrently, and with fail-safety

Two customers paying to an account at the same time can overwrite each other's changes

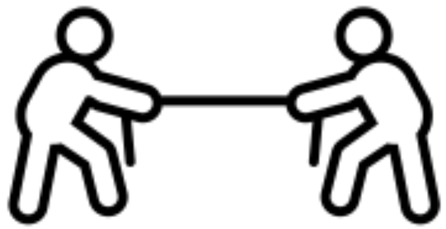


Account balance

How to maximize parallelism while maintaining correctness?

Transactions: ensuring complex operations run correctly, concurrently, and with fail-safety

parallelism



correctness

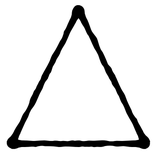
Trade & tune between these

Storage

Tables

Buffer Management

Indexes



Sorting

Operators

Query Optimization

Transactions

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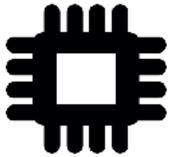
Recovery



CPU caches

memory

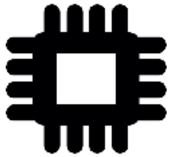
SSD

disk

volatile

Non-volatile

Recovery



CPU caches

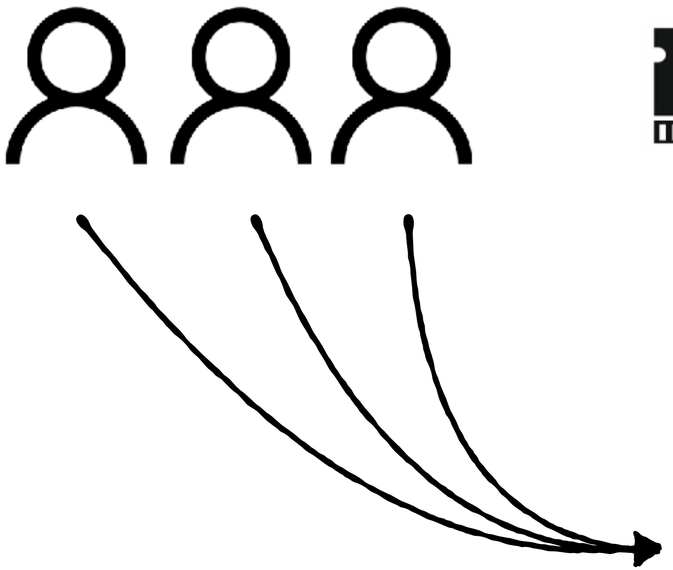
memory

SSD

disk

Data resides here for persistence

Recovery



memory

It is brought here to be updated

SSD

disk

Recovery

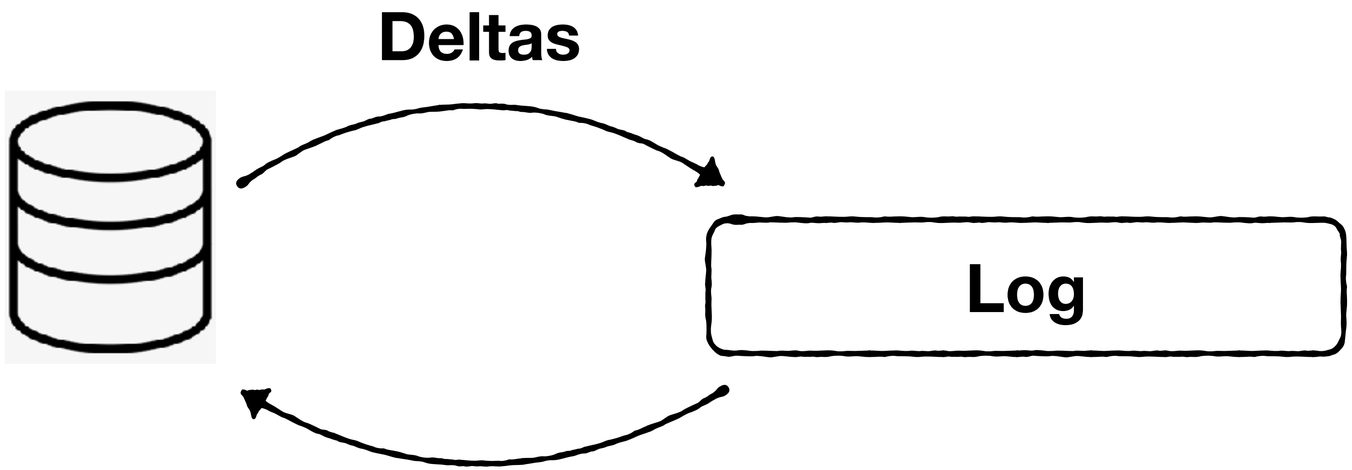
memory

SSD

disk

If power now fails, we lose everything

Recovery



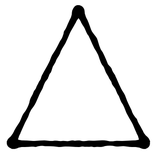
Efficient recovery

Storage

Tables

Buffer Management

Indexes



Sorting

Operators

Query Optimization

Transactions

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CSC2525: Research Topics in Database Management

Next semester

CSC2525: Research Topics in Database Management

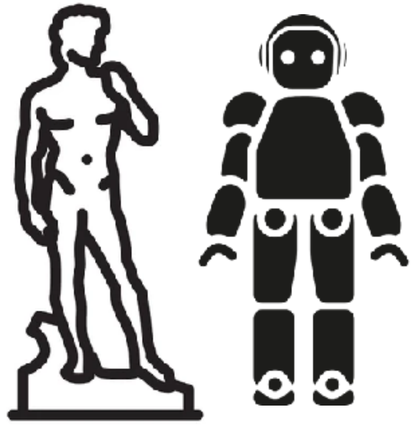
Next semester

Depth

CSC2525: Research Topics in Database Management

Next semester

Depth



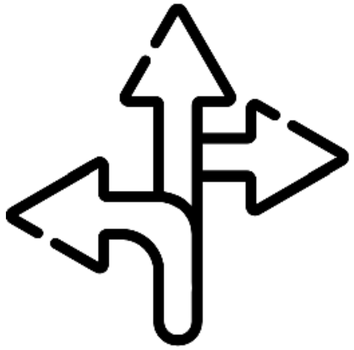
Classics & Research

Get involved in research

Get involved in research

Young field

Lots of directions



Lots to discover

After the break, we'll learn about disks & SSDs