CS460: Intro to Database Systems

Database System Architectures

Instructor: Manos Athanassoulis

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

logistics, goals, admin

database systems architectures

project details

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

Additional Readings

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


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

+research papers
Evaluation

Class Participation: 5%

In-class discussion

&

Collaborative Notes

2-3 students take notes (2 days after class anybody can augment it)

Shared Google doc: https://tinyurl.com/CS460-F21-Notes

[top part of website as well]

Enroll right after class!
Evaluation

Class Participation: 5%
Written Assignments: 10%

Graded on completion-basis
if you submit on time & >70% you get full credit
the goal of the assignments is to get familiar with exam-like questions

Throughout the semester
7 deadlines spread across the semester
[topics and deadline soon in the website]
Evaluation

Class Participation: 5%
Written Assignments: 10%
Programming Assignments: 30%

Three assignments throughout semester
[more details later today]
Evaluation

Class Participation: 5%
Written Assignments: 10%
Programming Assignments: 30%
Midterm: 20%
Final: 35%

(more details soon)
Evaluation

Class Participation: 5%
Written Assignments: 10%
Programming Assignments: 30%
Midterm: 20%
Final: 35%

Hands-on Bonus: 5% (SQL 3% & Key-value querying 2%)
Office Hours

OH are **in-person**
(online OH can be arranged when needed)

**Manos**
T/Th @ 3:30pm (after class)

**TAs**
announced in Piazza
a declarative box

I want “blah”

there you go

why having a declarative box is useful?
Database Systems

I want “blah”

there you go

a declarative box

**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

energy

DATA

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

![Graph showing total data center electricity consumption with various savings categories and energy efficiency trends.](https://datacenterknowledge.com)

- Data center electricity consumption (billion kWh)

- Infrastructure Savings
- Network Savings
- Storage Savings
- Server Savings

- Savings: 620 billion kWh

*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

- Query Compiler
- Transaction Manager
- Schema Manager
- Execution Engine
- Buffer Manager
- Storage Manager
- Logging/Recovery
- Concurrency Control

DBMS: a set of cooperating software modules

Physical storage very important for performance!
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 all students?

if I am interested in the GPA of student A?
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?

- rows first
- columns first

if I want to access all the information of a single student?
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?

I want “blah”

there you go

a declarative box

No!
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?

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<tr>
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<th>Name</th>
<th>DOB</th>
<th>Tel</th>
<th>email</th>
<th>GPA</th>
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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?

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simpler basic operators

complicated query logic (more operators to connect)
does that affect the way we apply *updates*?

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- 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

- hand coded
- OS
- key concepts
- first DB systems
- war OS vs. DBs
- object-oriented DBs
- declarative, abstractions, recovery, consistency

- perf & HW
- multi-core
- flash

- column stores, cache memories

- NoSQL vs. DBs
- NoSQL
- 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

design, implement, & document a database application for movies, actors, and reviews/user likes

(1) model and design the desired database
(2) augment the schema to support additional functionality
    (3) build an API to the database
    (4) build a web app that supports:
        (i) inserting new data, (ii) analysis queries, (iii) browsing

project in groups of 2
More Programming Assignments

*individual projects*

*rows vs. columns*

compare the two main paradigms

*query optimization*

understand the performance of a query
Piazza

Announcements & Discussions in Piazza

https://piazza.com/bu/fall2021/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