COMS W4111.001
Introduction to Databases
Fall 2022

Computer Science Department
Columbia University
Your Instructor: Luis Gravano

- Ph.D. in Computer Science, Stanford U.
- Professor, Computer Science Department (at Columbia U. since Fall 1997)
- At Google: Senior Research Scientist (2001), Visiting Faculty Researcher (2018-19)
- Research interests: Databases, Web Search, Information Extraction, Social Media
Class Resources

- Class website: http://www.cs.columbia.edu/~gravano/cs4111
- Discussion board: Ed Discussion, which you can access from CourseWorks, at https://courseworks.columbia.edu/
- Announcements from class staff: on CourseWorks
Your Instructor: Luis Gravano (he, him, his)

- [gravano@cs.columbia.edu](mailto:gravano@cs.columbia.edu)

- Office hours:
  - Mondays, 9:30-10:30 a.m. ET in person at 706 Schapiro CEPSR (masks appreciated)
  - Wednesdays, 9:30-10:30 a.m. ET online
  - By appointment by email

- Details and links on class website
Your TAs

Gursifath Bhasin    Ruchika Goel    Radhika Goyal    Ian Macleod

Samia Menon    Karthik Shetty    Yuan-Yi Wang

Office hours and their location or links will soon be on a Google Calendar in CourseWorks “Announcement”
Class Information: Prerequisites

COMS W3134 – Data Structures in Java, COMS W3136 – Essential Data Structures in C/C++, or COMS W3137 – Data Structures and Algorithms (equivalent courses taken elsewhere are acceptable as well)

You need permission from the instructor if you don’t have the prerequisites
Class Information: Lectures

- Tuesdays and Thursdays, 1:10-2:25 p.m. ET

- 3 formats, all equally OK and fully your choice:
  - In person, at 301 Pupin
  - On Zoom, using link in “Zoom Class Sessions” section on CourseWorks
  - As recordings, in “Video Library” section on CourseWorks
Lectures: In Person

- We all need to fully comply with the new Columbia Community Health Compact, https://covid19.columbia.edu/content/columbia-community-health-compact-new

- In particular, masks are required at all times in the classroom at least through September 30
Lectures: On Zoom

- Mute yourself but keep your video on during lectures as much as possible
- Ask questions in the Zoom chat, by using Zoom’s “raise hand” function, or simply by unmuting yourself

Questions are welcome and encouraged!
Grading Information

- **Midterm** (Thu Oct 27, during lecture time): 15%
- **Final** (Tue Dec 20, 1:10-3:10 p.m. ET, cumulative): 30%
- **Homework assignments** (4, all equally weighted): 15%
- **Projects** (2): 40%
  - Project 1: 30%, Project 2: 10%

- Midterm and final are closed book, closed notes

- Median grade will be a B+ or slightly higher
- Alternative or make-up exams will **not** be given
- All homework assignments are equally weighted
- Project 1 has higher weight than Project 2
Homework

• To be fair to all students in the class, I will grant no extensions or exceptions.
• Instead, you have three grace late days for homework that you can use as you wish throughout the semester; weekends and university holidays are not counted.
• After using all grace days, you will get a 25% grade deduction for each additional late day.

Check full details on website.
2 Projects, in Teams of 2 Students

• You will do the projects on the Google Cloud platform
• You will have more-than-enough free credit through individual codes that I will distribute once enrollments stabilize
• Projects will have a non-programming option
• If you follow the programming option, which I strongly recommend, you will program in Python (only language option):
  • Python is much easier to work with than Java for our database projects
  • Python is a great, easy-to-learn, widely used language
  • If you are fluent in Java, you will be able to easily learn the (not-so-deep) level of Python needed for our projects

• Project 1: model and build an application of your choice on top of a database system, using “traditional” relational database features
• Project 2: expand Project 1 to use substantial, advanced database system features

More details announced soon; please be patient and wait until projects announced
Projects (cont.)

• To be fair to all students in the class, I will grant no extensions or exceptions for project submission.

• Instead, you have three grace late days total for projects that you can use as you wish throughout the semester; weekends and university holidays are not counted.

• After using all grace days, you will get a 25% grade deduction for each additional late day.

Check full details on [website](#)
Collaboration Policy

- Please check “Collaboration and Academic Honesty” page from the main webpage for the class.
- Homework and exams are to be done individually.
- Projects are done in teams; no collaboration between different teams.
- We will not tolerate cheating, which would be wrong and unfair to the rest of the class. Check the CS Department policies and procedures regarding academic honesty at http://www.cs.columbia.edu/education/honesty; they fully apply to this course.
- Contact the instructor right away if you have any questions.
Optional Textbook


Textbook is optional: lectures will cover all material needed for homework assignments and exams

Textbook homepage has useful resources: https://db-book.com/
Project 1 Contest

- Four best projects chosen as contest winners

- If you win:
  - You will have the option to discuss and demonstrate your project in class
  - You will get a 10% boost in your Project 1 grade
Ongoing Feedback

• Don’t wait until the end-of-semester course evaluations to complain or give feedback on how to improve course (it’s too late then!)

• Talk to me early on during my office hours or send me email with your concerns and suggestions, or ask a TA to forward them to me
Thanks to Raghu Ramakrishnan, Johannes Gehrke, and our own Eugene Wu for some of the slides!
What Is a Database and a Database Management System (DBMS)?

- A **database** is a generally large, integrated collection of data that models a real-world enterprise
  - Entities (e.g., students, courses)
  - Relationships (e.g., Juana González is taking cs4111)

- A **database management system (DBMS)** is a software system designed to store, manage, and interact with databases
Why Use a DBMS?

- Data independence and efficient access
- Reduced application development time
- Data integrity and security
- Uniform data administration
- Concurrent access, recovery from crashes
Why Study Databases?

• Shift from computation to information

• Data sets increasing in diversity and volume
  • The Web, online activity and commerce, social media, …
  • … need for DBMS exploding

• DBMS encompasses most of CS
  • OS, languages, theory, AI, machine learning, natural language processing, multimedia, …
Why Study Databases?

- Most structured information on the web lives in databases
  - Projects 1 and 2 will give you the opportunity to understand their potential for data and a domain of your interest
- Databases are critical to organize, query, and perform data analysis (e.g., data mining) of scientific, business and financial, environmental, health data, and much more
- Also extremely helpful to organize large-scale experimental results and data
- Other types of data repositories, such as text content, covered in COMS E6111
Why are DBMSs Necessary?

Consider a bank with a simple “relation” with account information:
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<table>
<thead>
<tr>
<th>accountNo</th>
<th>balance</th>
<th>type</th>
</tr>
</thead>
<tbody>
<tr>
<td>12345</td>
<td>$1000</td>
<td>savings</td>
</tr>
<tr>
<td>54321</td>
<td>$250</td>
<td>checking</td>
</tr>
<tr>
<td>12345</td>
<td>$150</td>
<td>checking</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
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</table>

- Users can withdraw money from an account
- Users can transfer money between accounts
- Bank can ask queries such as **Q1: “list all accounts with a balance over $10K”**
Why not implement all this with a file system with some ad-hoc software?
How About Efficiency?
Providing “Transactional Guarantees”?
Expected Behaviors if You and Your Spouse Withdraw Money or Pay a Bill on Same Account Simultaneously?
Yes, We Could Write All Code for Our Applications Ourselves ...
Yes, We Could Write All Code for Our Applications Ourselves ... 

... in a few decades!

Luckily, this functionality (queries, query processing, transaction processing) is common across many applications, so we can factor it out
Database Courses at Columbia
(This course) COMS W4111-Introduction to Databases
Prerequisites: CS3134, CS3136, or CS3137

- The Entity-Relationship Model
- The Relational Model
- The Relational Algebra
- SQL: Queries, Constraints, Triggers
- Embedded SQL, Cursors, SQL APIs
- Schema Refinement and Normal Forms
- Object-Relational DBMS: Database Design
- Introduction to Query Processing and Optimization
- Introduction to Transaction Processing
COMS W4112-Database System Implementation
Prerequisites: CS4111; fluency in Java or C++; recommended: CS3827

- Storage Methods and Indexing
- Query Processing and Optimization for 1NF Relations, including External Sorting
- Materialized View Maintenance, Selection, and Use in Query Optimization
- Query Processing and Optimization for ORDBMSs
- Transaction Processing and Recovery
- Parallel and Distributed Databases: Query Processing and Optimization
- Parallel and Distributed Databases: Transaction Processing
- Performance Considerations Beyond I/Os
Overview of Database-Related Issues
Data Models

• A data model is a collection of concepts for describing data
• The relational model of data is the most widely used model today
  • Main concept: relation, basically a table with rows and columns
  • Every relation has a schema, which describes the columns, or fields

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Levels of Abstraction

- Many views, single conceptual (logical) schema, and physical schema
  - Views describe how users see the data
  - Conceptual schema defines logical structure
  - Physical schema describes files and indexes used

- Schemas are defined using a data definition language (DDL)
- Data is modified and queried using a data manipulation language (DML)
Example: University Database

- **Conceptual schema:**
  - Students(sid:string, name:string, login:string, age:integer, gpa:real)
  - Courses(cid:string, cname:string, credits:integer)
  - Enrolled(sid:string, cid:string, grade:string)
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  - Relations stored as unordered files
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• **External schema (view):**
  • Course_info(cid:string, cname:string, enrollment:integer)
Data Independence

• Applications insulated from how data is structured and stored
• Logical data independence: Protection from changes in logical structure of data
• Physical data independence: Protection from changes in physical structure of data

• One important benefit of using a DBMS
Concurrent execution of user programs is essential for good DBMS performance.

Interleaving actions of different user programs can lead to inconsistency: what if check is cleared while account balance is being computed?

DBMS ensures such problems don’t arise: users can pretend they are using a single-user system.
Transaction: An Execution of a Database “Program”

- Key concept: transaction, an atomic sequence of database actions
  - Example: Transferring funds from one account to another, which requires multiple operations over bank database

- DBMS guarantees important properties of transactions automatically, without user involvement:
  - Preserving consistency of database contents
  - Handling crashes gracefully, without ever losing any data
  - Allowing concurrent execution in a controlled manner that doesn’t create any problems
Summary

• DBMS used to maintain, query large databases
• Benefits include recovery from system crashes, concurrent access, quick and flexible application development, data integrity and security
• Levels of abstraction give data independence
• Databases is one of the broadest, most useful research and development areas in Computer Science