Database Systems (CS-UH 2214)

Spring 2022

Instructor:	Azza Abouzied azza@nyu.edu	Lectures:	MW 2:40 – 3:55 Online - Feb 4*; C1-120
TA:	Hazem Ibrahim hazem.ibrahim@nyu.edu	Office Hrs:	TBD or By appointment

Course Description: This course introduces students to the foundations of database systems, focusing on basics such as data models, especially the relational data model, query languages, query optimization and processing, indices and other specialized data structures, as well as transactions and concurrency control. Students build components of a database system and through research readings understand the design complexities of transactional and big data analytical systems.

Course Links:

Course Book	azzadev.github.io/dbcrsbook
Course zoom link	https://nyu.zoom.us/j/92541974667

The course book is the online central resource for all video lectures, reading materials, links to assigned assessments, etc.

Course textbook:

- Raghu Ramakrishnan and Johannes Gehrke. **Database Management Systems**. 3rd. McGraw-Hill, Aug. 2002.

Reference textbooks:

- Peter Bailis, Joseph Hellerstein, and Michael Stonebraker. **Readings in Database Systems**. 5th. 2015. URL: `http://www.redbook.io/`.

Getting help: The course slack channel is database-systems-org.slack.com. You can send questions to the private spring 2022 channel (all other channels are restricted where course instructors may post general information) or DM the course instructors on slack.

You can also set up an appointment for office hours with any of the instructors. On certain weeks, Wednesday's class is an open office hour, lab recitation, or patch-the-gap session. Azza's office hours are still TBD.

Learning Outcomes:

- Design and implement a database for any application that provides good transactional performance and maintains data consistency guarantees
- Query and analyze data within a database
- Explain data storage, access, index and query optimization techniques employed by relational database systems
- Estimate and evaluate the performance of different query workloads and fine-tune database performance
- Understand the components of a DBMS by implementation through a series of programming-intensive labs
- Explain how a database system can allow multiple users to concurrently query and update the same data and preserve data consistency even in the face of failures
- Explain how distributed databases provide ACID transactions
- Explain the tradeoffs made by different database architectures and newSQL or noSQL systems
- Synthesize a set of design principles that are useful for building large data processing systems

- Study how one can break down fundamental assumptions about hardware or workload expectations to redesign novel database systems.

Teaching Methodologies:

- *Online Lectures*: This course is *flipped*! All lectures will be provided asynchronously, online through the course book. The book is split into 14 modules. Each week covers a specific module.

  Online/in-person class meetings will be a combination of *in-class interactive exercises* where you are expected to participate and *patch the gap* sessions where we cover concepts that are somewhat tricky.

- *Readings*: Each weekly module will begin with the assigned reading material. You should read these in addition to listening to the online video lectures, and reading the online course book notes. By keeping on top of the readings, you will be better prepared to take the online weekly assessment and you can better participate in class and you can clarify concepts you found difficult to understand.

- *Collaborative work*: You will work with your peers to complete your programming-intensive labs. Effective team work is crucial for developing large software systems.

- *Labs*: You will complete a set of programming-intensive group labs to build the different components of SimpleDB[1]. By implementing the building blocks of a database system, you apply the concepts learned in class. A condition of using MIT's SimpleDB code base is not to distribute/share your solutions. All assignment resources are therefore distributed through NYU Drive. Solutions must be submitted securely and you should not publish your solutions online.

- *Weekly Online Assessments*: In lieu of midterms and final exams, you will have to complete 11-14 online assessments, roughly one for each week. Assessments are due on **Saturday** and discussed in class on the following Monday. You have an entire week to complete each assessment. Links for each assessment will be found in the relevant module's course book page.

  This course emphasizes ***independent and active learning***. You need to read the assigned material, and follow the online lectures to successfully complete the assessment. Some Wednesday classes are dedicated office hours to help students understand any material they found confusing.

Course Deliverables:

2-3 Labs	25%
2-3 Problem Sets	25%
10-14 Weekly Assessments	45%
Bonus and Class Participation	≈5%

The exact grade breakdown may change. If this happens, the course instructor will notify students in a reasonable time. Alternative or additional course work is possible and can substitute the marks of a certain assessment or course deliverable. This needs to be discussed with and agreed to by the instructor ahead of time.

Grading Policy: In general, a 90% or above is within the A range, 80%-90% is within the B range and 70%-80% is within the C range.
You have **100 hours of lateness forgiveness** that you can use throughout the course for any problem set or lab submission deadline.

[1] **MIT SimpleDB Labs for 6.830**. URL: https://github.com/MIT-DB-Class/course-info/blob/master/lab1.md.

Course Schedule:

The following is a tentative course schedule. Exact release and due dates of labs and problem sets may change. Weekly assessments are due every Saturday at 9:00 PM Abu Dhabi time. Weekly modules may be extended, shrunk, shifted or re-ordered.

Week	Lectures, Readings, Assignments
0	**Overview & Introduction to Database Systems** *Reading:* Bailis, J. Hellerstein, and Michael Stonebraker, *Readings in Database Systems*, What Goes Around, Comes Around
1	**The Relational Model** *Reading:* Ramakrishnan and Gehrke, *Database Management Systems*, Chp 4-4.25, Chp 2-2.6, Sec 3.5 *Optional Reading:* Codd, "A Relational Model of Data for Large Shared Data Banks"
2	**Querying Languages & SQL** *Reading:* Ramakrishnan and Gehrke, *Database Management Systems*, Chp 5, 6 *Optional Reading:* Cohen et al., "MAD Skills: New Analysis Practices for Big Data" *Assignment:* Problem Set 1 - Analyzing the DBLP dataset (2 weeks)
3	**Schema Design & Normalization** *Reading:* Ramakrishnan and Gehrke, *Database Management Systems*, Chp 19-19.4
4	**Introduction to DB internals** *Reading:* Ramakrishnan and Gehrke, *Database Management Systems*, Chp 9.3-9.7 *Optional Reading:* J. M. Hellerstein, Michael Stonebraker, and Hamilton, "Architecture of a Database System"
5	**Buffer Pools & Memory Management** *Reading:* Ramakrishnan and Gehrke, *Database Management Systems*, Chp 9.4 *Optional Reading:* Chou and DeWitt, "An Evaluation of Buffer Management Strategies for Relational Database Systems" *Assignment:* Lab 1: The Catalog, Heap File and Buffer Pool (2 weeks)
6	**Access Methods** *Reading:* Ramakrishnan and Gehrke, *Database Management Systems*, Chp 10
7	**Indexing & Hashing** *Reading:* Ramakrishnan and Gehrke, *Database Management Systems*, Chp 13, 28.1–28.3.1, 28.6, 11 *Optional Reading:* Beckmann et al., "The R*-tree: An Efficient and Robust Access Method for Points and Rectangles"
8	**Query Processing** *Reading:* Ramakrishnan and Gehrke, *Database Management Systems*, Chp 12.4 *Assignment:* Lab 2: Query Operators (2 weeks)
9	**Sorting, Grouping & Aggregating** *Reading:* Ramakrishnan and Gehrke, *Database Management Systems*, Chp 13, 14.5, 14.6
10	**Joins** *Reading:* Ramakrishnan and Gehrke, *Database Management Systems*, Chp 14.4 *Optional Reading:* Shapiro, "Join Processing in Database Systems with Large Main Memories"

11 **Query Optimization**
Reading: Ramakrishnan and Gehrke, *Database Management Systems*, Chp 12.4-7, 15.1, 15.3–7
Optional Reading: Selinger et al., "Access Path Selection in a Relational Database Management System"
Optional Reading: Mannino, Chu, and Sager, "Statistical Profile Estimation in Database Systems"
Assignment: Problem Set 2: Query Optimization with Postgres (2 weeks)

12 **ACID Transactions & Concurrency Control**
Reading: Ramakrishnan and Gehrke, *Database Management Systems*, Chp 16.1-3 and 17.1, Chp 16.4-16.6, 17.1–17.5
Optional Reading: Franklin, "Concurrency Control and Recovery"
Optional Reading: Kung and Robinson, "On Optimistic Methods for Concurrency Control"

13 **Recovery**
Reading: Ramakrishnan and Gehrke, *Database Management Systems*, Chp 18
Optional Reading: Mohan, Haderle, et al., "ARIES: A Transaction Recovery Method Supporting Fine-granularity Locking and Partial Rollbacks Using Write-ahead Logging"

14 **Distributed Databases & Transactions**
Reading: Ramakrishnan and Gehrke, *Database Management Systems*, Chp 22.6-22.8, 22.11-22.14)
Optional Reading: Mohan, Lindsay, and Obermarck, "Transaction Management in the R* Distributed Database Management System"
Optional Reading: Bailis, J. Hellerstein, and Michael Stonebraker, *Readings in Database Systems*, Chp 6: Weak Isolation and Distribution
Optional Reading: Brewer, "CAP twelve years later: How the "rules" have changed"

References for Additional or Optional Course Readings:

- Andrew Pavlo and Matthew Aslett. **What's Really New with NewSQL?** In: *SIGMOD Rec.* 45.2 (Sept. 2016), pp. 45–55. URL: https://doi.org/10.1145/3003665.3003674.
- Azza Abouzeid et al. **HadoopDB: An Architectural Hybrid of MapReduce and DBMS Technologies for Analytical Workloads**. In: *Proc. VLDB Endow.* 2.1 (Aug. 2009), pp. 922–933. URL: http://dx.doi.org/10.14778/1687627.1687731.
- Jeffrey Cohen et al. **MAD Skills: New Analysis Practices for Big Data**. In: *Proc. VLDB Endow.* 2.2 (Aug. 2009), pp. 1481–1492. URL: http://dx.doi.org/10.14778/1687553.1687576.
- Jeffrey Dean and Sanjay Ghemawat. **MapReduce: Simplified Data Processing on Large Clusters**. In: *Commun. ACM* 51.1 (Jan. 2008), pp. 107–113. URL: http://doi.acm.org/10.1145/1327452.1327492.
- Joseph M. Hellerstein, Michael Stonebraker, and James Hamilton. **Architecture of a Database System**. In: *Found. Trends databases* 1.2 (Feb. 2007), pp. 141–259. URL: http://dx.doi.org/10.1561/1900000002.
- Michael J. Franklin. **Concurrency Control and Recovery**. In: *The Computer Science and Engineering Handbook*. Ed. by Allen B. Tucker. CRC Press, 1997, pp. 1058–1077. URL: http://bit.ly/2g6oC6R.
- C. Mohan, Don Haderle, et al. **ARIES: A Transaction Recovery Method Supporting Fine-granularity Locking and Partial Rollbacks Using Write-ahead Logging**. In: *ACM Trans. Database Syst.* 17.1 (Mar. 1992), pp. 94–162. URL: http://doi.acm.org/10.1145/128765.128770.
- Norbert Beckmann et al. **The R*-tree: An Efficient and Robust Access Method for Points and Rectangles**. In: *SIGMOD Rec.* 19.2 (May 1990), pp. 322–331. URL: http://doi.acm.org/10.1145/93605.98741.
- Michael V. Mannino, Paicheng Chu, and Thomas Sager. **Statistical Profile Estimation in Database Systems**. In: *ACM Comput. Surv.* 20.3 (Sept. 1988), pp. 191–221. URL: http://doi.acm.org/10.1145/62061.62063.
- C. Mohan, B. Lindsay, and R. Obermarck. **Transaction Management in the R* Distributed Database Management System**. In: *ACM Trans. Database Syst.* 11.4 (Dec. 1986), pp. 378–396. URL: http://doi.acm.org/10.1145/7239.7266.
- Leonard D. Shapiro. **Join Processing in Database Systems with Large Main Memories**. In: *ACM Trans. Database Syst.* 11.3 (Aug. 1986), pp. 239–264. URL: http://doi.acm.org/10.1145/6314.6315.
- Hong-Tai Chou and David J. DeWitt. **An Evaluation of Buffer Management Strategies for Relational Database Systems**. In: *Proceedings of the 11th International Conference on Very Large Data Bases - Volume 11*. VLDB '85. Stockholm, Sweden: VLDB Endowment, 1985, pp. 127–141. URL: http://dl.acm.org/citation.cfm?id=1286760.1286772.

- H. T. Kung and John T. Robinson. **On Optimistic Methods for Concurrency Control**. In: *ACM Trans. Database Syst.* 6.2 (June 1981), pp. 213–226. URL: http://doi.acm.org/10.1145/319566.319567.
- P. Griffiths Selinger et al. **Access Path Selection in a Relational Database Management System**. In: *Proceedings of the 1979 ACM SIGMOD International Conference on Management of Data*. SIGMOD '79. Boston, Massachusetts: ACM, 1979, pp. 23–34. URL: http://doi.acm.org/10.1145/582095.582099.
- E. F. Codd. **A Relational Model of Data for Large Shared Data Banks**. In: *Commun. ACM* 13.6 (June 1970), pp. 377–387. URL: http://doi.acm.org/10.1145/362384.362685.

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