CSE 215 Syllabus
Winter 2020

Instructor:
Sheldon (Shel) Finkelstein

CSE 215, Winter 2020

Design and Implementation of Data Management Systems

Classes: MWF, 9:20AM-10:25AM, E2-192

Instructor: Sheldon (Shel) Finkelstein, shel@ucsc.edu

Office Hours: TBD, **E2-249B**
   Also, available by appointment.

Course page on Piazza:

   https://piazza.com/ucsc/winter2020/cse215/home

Some Background: Shel Finkelstein

- IBM Almaden Research: Database and Distributed Systems
- Tandem Computers: Transaction Management and System Managed Storage
- Illustra Information Systems: Productizing Postgres (Time Series, Administration)
- ADB/Matisse (Object Database): Chief Scientist
- Sun Microsystems: Managed Enterprise Java architecture and partnership relationships when Java Enterprise Edition was created
- SAP: VP, Research Fellow, Chief Tech Architect, focusing on Applications and Database
- Teaching as Lecturer at UC Santa Cruz since January 2015, mainly Database courses

CSE 215 Description

CSE 215 is an advanced course in the implementation of data management systems, including (but not limited to) databases.

The class is of interest to students who wish to either do research on data management systems or learn more about scalable data management systems.

CSE 215 used to be called CMPS 278, and I've taught it a number of times before, using approximately the same approach described in this Syllabus.

CSE 215 Topics

Topics <u>may</u> include some of the following, as well as other topics, depending on student interests:

- Processing large volumes of data
- Access paths
- Query optimization
- Concurrency control
- Database recovery
- Parallel and distributed data management systems
- Approximate query answering
- Heterogeneous data systems
- Column databases
- Analytics/OLAP
- In-memory systems
- Semi-structured data
- Streaming data
- Scientific Data
- Data Security
- Hardware-accelerated databases

Seminar Prerequisite

- Enrolled students are expected to have a basic background in relational database systems, approximately equivalent to CMPS 181 or chapters 8-18 of [Database Management Systems](), 3rd Edition by Ramakrishnan and Gehrke. Students not familiar with that material are strongly urged to familiarize themselves with it during the course.
  - But we'll devote first 4 Lectures to going over some basic material from that course, so that everyone has some common background.
  - If student have time--not required--they might look at some of the great [Lectures by Prof. Andy Pavlo of CMU]() that are available on [YouTube]()
- Another good data system overview that we'll review early in the course is "Architecture of a Database System" by Joseph M. Hellerstein, Michael Stonebraker and James Hamilton, which is available on-line at: http://db.cs.berkeley.edu/papers/fntdb07-architecture.pdf

Some Seminar Materials

Some (not all) of the papers we'll be discussing are in "Readings in Database Systems", 5th Edition, edited by Peter Bailis, Joseph M. Hellerstein and Michael Stonebraker. The book is available at http://www.redbook.io/, although you'll have to search for the actual papers using Google Scholar.

If you think that everything's been done:

- New applications, new algorithms, new hardware, more hardware, more data, different kinds of data, different consistency requirements, etc.
- Listen to Mike Stonebraker YouTube talk on One Size Fits None, 2015's ten year ICDE Influential Paper Award Talk for 2005 ICDE Paper One Size Fits All: An Idea Whose Time Has Come and Gone

Some recent advanced systems research and practice:

- 2019 Conference on Innovative Database Research (CIDR) program
- 2019 High Performance Transaction Systems (HPTS) Workshop program
- Also SOSP, OSDI, NSDI, SIGMOD, VLDB and much more …

CSE 215 Requirements

Students are expected to:

- Present talks two or more papers.
    - Signup will be available no later than Wednesday, January 15.
- Write <u>brief</u> Evaluations of each Paper we're discussing, sent to me <u>before</u> paper is presented in class.
    - Submit Evaluations using Canvas; late evaluations won't be accepted.
    - Login to Canvas at https://login.uconline.edu using your CruzID and Gold password. CSE 215 should be one of the classes available.
    - Info on Canvas is at http://its.ucsc.edu/fitc/canvas/
- Participate in class discussions of papers—this is a seminar!
- Do a Course Project, which involves a paper and a presentation

CSE 215 Grading

- 10%: General class participation—this is a seminar!
- 30%: Paper Presentation(s) in class
- 20%: Paper Evaluations
- 40%: Course Project

Paper Presentation(s)

- Presentation should show that you've read the Paper(s) thoughtfully.
  - Try to involve the entire class in discussion of concepts of paper and contribution of paper.
- Usually, I'll be able to point you to slides prepared by authors of Paper that you may want to use in your presentation.
  - But you're presenting your thoughts about the importance of the Paper, so just repeating authors' opinion (when they wrote the Paper) isn't enough.
- It may be worthwhile to choose Paper that relates to your Course Project …
  - … but that's not required.

Signing Up for Papers

- Please send me email with subject "Paper Presentations" by Wednesday, January 8, letting me know:
    1. Which topics interest you most
    2. When topics you might like to present

- Some potential advantages for students who present early
    o They complete a required presentation quickly.
    o They get a head start on topics that might be the basis for course projects.
    o Their subject preferences on papers are somewhat more likely to be honored.
    o They shows initiative by being early presenters, which I appreciate!

Paper Evaluation Questions

1. How does the authors' approach to the problem that they are solving improve on previous approaches?

   – About 3 sentences!

2. Provide 2 or more <u>thoughtful</u> comments or questions.

*Note: Abstract, intro and conclusion in papers may help you with some of these questions, but **do not copy text** from papers.*

- Evaluations are due on Canvas by 5pm on the day before Paper Presentation.
- No Evaluation required for my presentations during first 4 Lectures, or for presentations by External Speakers.

Course Projects

- Your CSE 215 Course Project involves both:
  - A paper describing project (approximately 10 pages, not more than 20) due by last day of classes, **and …**
  - A 30 minute class presentation during last week of classes or during Finals Week.

- Ideally, Course Projects should be proposed and approved by me by the end of the third week of classes, Friday, January 24.
  - No later than the end of the fifth week of classes, **Friday, February 7.**
  - Hey, quarters are only 10 weeks long …

- Although class projects are best done individually, a class project may also be done by a team of 2 people (not more), but only if:
  - the project is substantial enough, and
  - the role of each person is well-defined, and
  - each person can (relatively) independently complete their part.

Course Projects: Examples

Students are particularly encouraged to study Open Source data management systems (there are many) and do something like one of the following:

- Compare performance of multiple systems for an application
- Show how multiple systems can be used together effectively to perform a significant task
- Make a non-trivial change to an open source system, show how it can be used, and evaluate the change
- Evaluate scalability, availability or other aspects of an open source system
- Design and do some implementation of a novel data management system of your own
- Evaluate use of an existing or new data management approach for a specific application area

Course Projects: More Examples

Here are some possibilities that don't involve implementation (but remember that implementation projects are preferred!)

- Review of a PhD thesis, or of a series of papers not covered in class.

- Summarize the state of technology in a particular area based on reading recent papers and/or reading/seeing recent presentations.

- Survey key emerging problems and solutions for a technical area, such as privacy and security.

- Describe tradeoffs among alternative solutions to some application problem, with at least a decent paper design for multiple solutions.

CMPS 278: Winter 2017 Presentations

CMPS 278 Winter 2018 Schedule

Date	Topic	Presenter	Paper
M, Jan 8	Intro	Shel Finkelstein	Architecture of a Database System, Hellerstein, Stonebraker and Hamilton
W, Jan 10	Indexing and Access Paths	Shel Finkelstein	Indexing slides from CMPS 181
F, Jan 12	Concurrency Control	Shel Finkelstein	Concurrency slides from CMPS 181
M, Jan 15	Holiday	no class	no class
W, Jan 17	Recovery	Shel Finkelstein	Logging slides from CMPS 181
F, Jan 19	Optimization	Shel Finkelstein	Optimization slides from CMPS 181
M, Jan 22	Recovery		Write-Behind Logging
W, Jan 24	Big Data, Recovery and Cloud		Amazon Aurora: Design Considerations for High Throughput Cloud-Native Relational Databases
F, Jan 26	Big Data and Cloud	Raghu Ramakrishnan, Microsoft	Microsoft Azure and Data Lakes
M, Jan 29	Access Structures		The Log-Structured Merge-Tree (LSM Tree), O'Neil et. Al.
W, Jan 31	Large Parallel Systems		Bigtable: A Distributed Storage System for Structured Data
F, Feb 2	Access Structures		Optimizing Space Amplification in RocksDB
M, Feb 5	Large Parallel Systems		MapReduce: Simplified Data Processing on Large Clusters, Dean and Ghemawat
W, Feb 7	Large Parallel Systems		Resilient Distributed Datasets: A Fault-Tolerant Abstraction for In-Memory Cluster Computing
F, Feb 9	Distributed Computing	C. Mohan, IBM	Blockchains and Database
M, Feb 12	Large Parallel Systems	Shel Finkelstein	Spark SQL: Relational Data Processing in Spark
W, Feb 14	Measurement and Testing	Kyle Kingsbury, Jepsen	Jepsen: Measuring and Breaking Databases
F, Feb 16	Security		CryptDB: Protecting Confidentiality with Encrypted Query Processing
M, Feb 19	Holiday	no class	no class
W, Feb 21	Large Parallel Systems	Jordan Tigani, Google	Google Dremel and BigQuery
F, Feb 23	Scalability, OLTP		F1: A Distributed SQL Database That Scales (also discussing Spanner a little)
M, Feb 26	Scalability, Streaming	Shel Finkelstein	Discretized Streams: Fault-Tolerant Streaming Computation at Scale (Spark Streaming)
W, Feb 28	Scalability, Streaming		Twitter Heron: Stream Processing at Scale, Kulkarni et al.
F, Mar 2	Scalability, OLTP		Eliminating Unscalable Communication in Transaction Processing
M , Mar 5	Multicore, OLTP	Danica Porobic, Oracle	Smoothing Non-Uniform Communication Latencies for OLTP
W, Mar 7	Multicore, In-Memory DB		Speedy Transactions in Multicore In-Memory Databases (Silo)
F, Mar 9	Multicore, In-Memory DB	Shel Finkelstein	SAP HANA: Delivering A Data Platform for Enterprise Applications on Modern Hardware
M , Mar 12	Concurrency Control		An Evaluation of Distributed Concurrency Control
W, Mar 14	Big Data, OLAP		The Case For Heterogeneous HTAP
F, Mar 16	Scalability, Consistency	Shel Finkelstein	Scalable Atomic Visibility with RAMP Transactions

CMPS 278: Fall 2018 Presentations

CMPS 278 Winter 2018 Schedule

Date	Topic	Presenter	Paper
F, Sept 28	Intro	Shel Finkelstein	Architecture of a Database System, Hellerstein, Stonebraker and Hamilton
M Oct 1	Indexing and Access Paths	Shel Finkelstein	Indexing slides from CMPS 181
W Oct 3	Optimization	Shel Finkelstein	Optimization slides from CMPS 181
F, Oct 5	Concurrency Control	Shel Finkelstein	Concurrency slides from CMPS 181
M, Oct 8	Recovery	Shel Finkelstein	Logging slides from CMPS 181
W, Oct 10	Multicore, In-Memory DB	Shel Finkelstein	SAP HANA: Delivering A Data Platform for Enterprise Applications on Modern Hardware
F, Oct 12	Recovery	Joy Arulraj, CMU/Georgia Tech	Data Management on Non-Volatile Memory
M, Oct 15	Access Structures		The Log-Structured Merge-Tree (LSM Tree), O'Neil et. Al.
W, Oct 17	Multicore, In-Memory DB		Speedy Transactions in Multicore In-Memory Databases (Silo)
F, Oct 19	Scalability, OLTP		F1: A Distributed SQL Database That Scales (also discussing Spanner a little)
M, Oct 22	Large Parallel Systems		MapReduce: Simplified Data Processing on Large Clusters, Dean and Ghemawat
W, Oct 24	Large Parallel Systems	Shel Finkelstein	Bigtable: A Distributed Storage System for Structured Data
F, Oct 26	Large Parallel Systems		Resilient Distributed Datasets: A Fault-Tolerant Abstraction for In-Memory Cluster Computing
M, Oct 29	Big Data, Recovery and Cloud	Kamal Gupta & Sailesh Krishnamurthy, AWS	Amazon Aurora: Design Considerations for High Throughput Cloud-Native Relational Databases
W, Oct 31	Streaming, Scalability		Discretized Streams: Fault-Tolerant Streaming Computation at Scale
F, Nov 2	Optim, OLAP, In-Mem DB		The MemSQL Query Optimizer
M, Nov 5	Optimization, Learning		Predicting Multiple Metrics for Queries: Better Decisions Enabled by Machine Learning
W, Nov 7	Access Paths, Learning	Neoklis Polyzotis, Google	Machine learning for data management and data management for machine learning
F, Nov 9	Multicore, In-Memory DB		Cicada: Dependably Fast Multi-Core In-Memory Transactions
M, Nov 12	Holiday	no class	no class
W, Nov 14	Scalability, OLTP	Shel Finkelstein	Eliminating Unscalable Communication in Transaction Processing
F, Nov 16	Concurrency Control		An Evaluation of Distributed Concurrency Control
M, Nov 19	Access Paths, Files	Siying Dong, Facebook	Optimizing Space Amplification in RocksDB
W, Nov 21	Scalability, Graph Engine		GraphX: Graph Processing in a Distributed Dataflow Framework
F, Nov 23	Holiday	no class	no class
M, Nov 26	Consistency, Scalability		Scalable Atomic Visibility with RAMP Transactions
W, Nov 28	Provenance, Privacy, IoT	Margo Seltzer, U. British Columbia	An NVM Carol
F, Nov 30	Data Cleaning, Scalability	Shel Finkelstein	Data Curation at Scale: The Data Tamer System
M, Dec 3	Big Data, OLAP, Federation		The Myria Big Data Management and Analytics System and Cloud Service
W, Dec 5	Query Execution, Federation		NoDB: efficient query execution on raw data files
F, Dec 7	Big Data, OLTP, OLAP		The Case For Heterogeneous HTAP

Fall 2019 External Speakers

- Joy Arulraj, CMU/Georgia Tech, on "Write-Behind Logging" and other uses of Non-Volatile Memory in Database
  - Hangouts presentation
- Kamal Gupta/Sailesh Krishnamurthy, Amazon Web Services, on "Deep Dive on Amazon Aurora", cloud-based MySQL (and PostgreSQL)
- Siying Dong, Facebook, on "RocksDB" and some other Data Management work at Facebook
- Neoklis (Alkis) Polyzotis, Google, on "The Case for Learned Index Structures"
- Margo Seltzer, U. Washington, "An NVM Carol"

Winter 2020 External Speakers

- Being determined
- This quarter, I'm focusing mostly on speakers from startups and less established companies

Interim Title IX Disclosure Statement

- Please be aware that under the [UC Policy on Sexual Violence and Sexual Harassment](), faculty and student employees (including Teaching Assistants, Readers, Tutors, etc.) are "responsible employees" and are **required** to notify the Title IX Officer of any reports of incidents of sexual harassment and sexual violence (sexual assault, domestic and dating violence, stalking, etc.) involving students. Academic freedom exceptions exist for disclosures made within a class discussion or assignment *related to course content*; under those conditions <u>only</u>, a report to the Title IX Officer is <u>not</u> required.

- The Campus Advocacy Resources and Education (CARE) Office (831) 502-2273, care@ucsc.edu can provide confidential support, resources, and assist with academic accommodations. To make a Title IX report, please contact Tracey Tsugawa, Title IX Officer, (831) 459-2462, ttsugawa@ucsc.edu.

Academic Integrity

- No form of academic dishonesty will be tolerated. You are encouraged to read the campus policies regarding academic integrity at https://www.ue.ucsc.edu/academic_misconduct. Violations may lead to penalties including (but not limited to) failing this course.

- You are allowed to ask for some help when working on assignments, provided that you acknowledge the help that you received on the work that you turn in.

- Points will be deducted if it appears that labor has been divided among multiple students; otherwise, there will be no penalty for small amounts of acknowledged assistance.

- If you have any questions about these rules, please discuss them with the instructor immediately.

Disability Resource Center

Special Accommodations:

UC Santa Cruz is committed to creating an academic environment that supports its diverse student body. If you are a student with a disability who requires accommodations to achieve equal access in this course, please submit your Accommodation Authorization Letter from the Disability Resource Center (DRC) to me privately during my office hours or by appointment, preferably within the first two weeks of the quarter.

At that time, I would also like us to discuss ways we can ensure your full participation in the course. I encourage all students who may benefit from learning more about DRC services to contact DRC by phone at 831-459-2089, or by email at drc@ucsc.edu.

Student responsibilities are as follows:

1. Students contact the DRC to determine their eligibility for accommodations. Students will request and receive their accommodation letter. This letter is provided to the instructor. This is official notice of a request for accommodation.
2. Students then notify their instructor during office hours or after class of their accommodations, and provide their instructor with their Accommodation Letters, **preferably during the first two weeks of the term**.
3. Students will manage their own disclosure of disability status, which will be maintained confidentially according to UC Santa Cruz data practices.

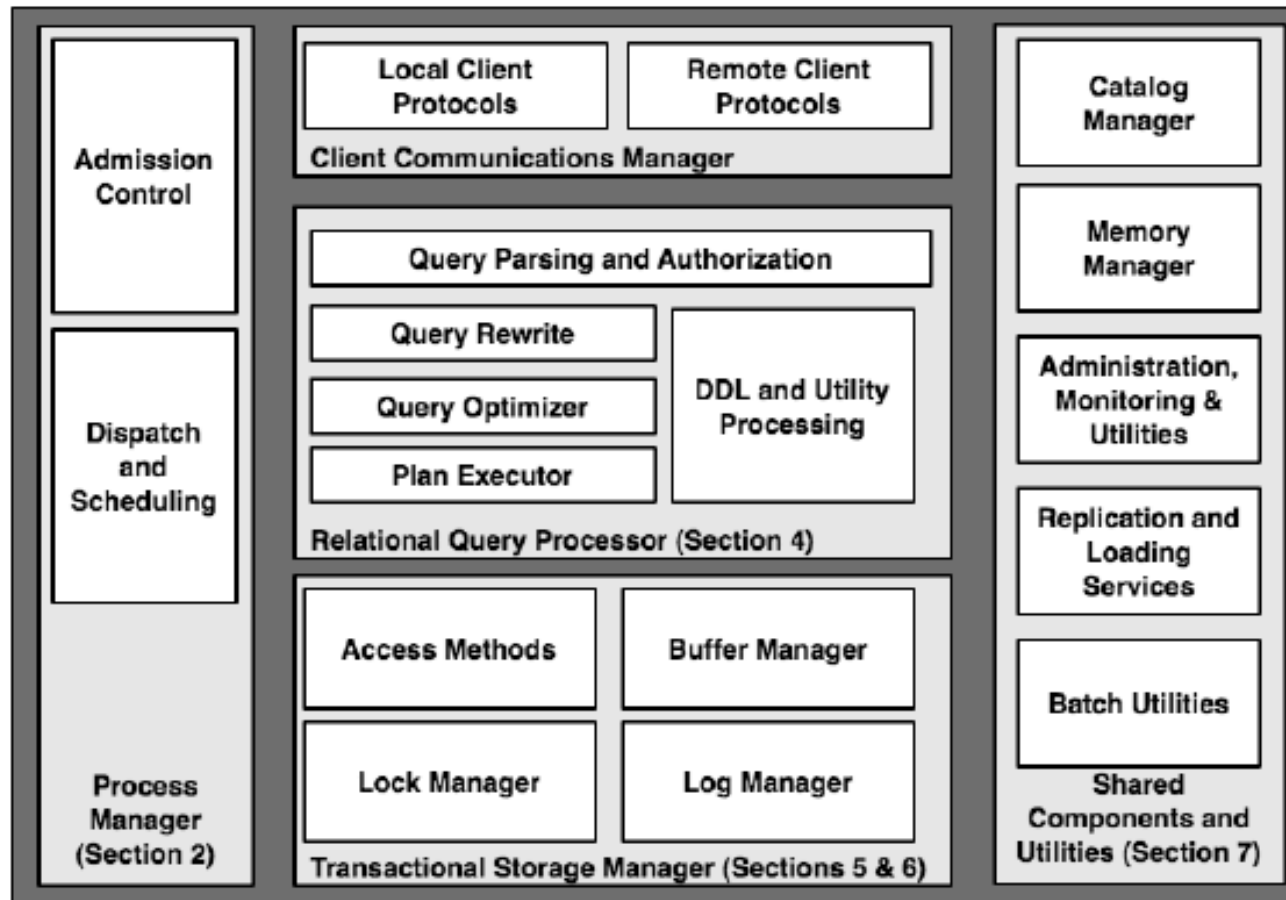# "Architecture of a Database System" by Joseph M. Hellerstein, Michael Stonebraker and James Hamilton

Fig. 1.1 Main components of a DBMS.