# Implementation of Database Systems

Fall 2021

| **Instructor:** | Amir Hossein Rouhani Seraji | **Code:** | 13755 |
|---|---|---|---|
| **Email:** | ah.rouhaniseraji@gmail.com | **Unit:** | 3 |

**Course Pages:** Please check this website two or three times a week

- https://rouhani-class.github.io/idbms001

**Discussion Group:** Every student has to be a member of our Telegram Channel and Telegram Group for our discussion and daily announcements.

- Telegram Channel.

- Telegram Group.

**Teaching Assistant:**

- Mehran Moeini Jam.

- Mohammad Hossein Khoshechin.

**Prerequisites:** An undergraduate-level understanding of Relational Databases Concepts, Data Structures, and Algorithms Design & Analysis.

**Objectives:** This is an upper-level course on the internals of database management systems. This course is on the design and implementation of database management systems. Topics include storage models (n-ary, decomposition), storage architectures (heaps, log-structured), indexing (order preserving trees, hash tables), transaction processing (ACID, concurrency control), recovery (logging, checkpoints), query processing (joins, sorting, aggregation, optimization), and parallel architectures (multi-core, distributed). Upon successful completion of this course, the student should be able to: Implement a disk-oriented database storage manager with table heaps and indexes. Understand, compare, and implement the fundamental concurrency control algorithms. Implement database recovery algorithms and verify their correctness. Identify trade-offs among database systems techniques and contrast distributed/parallel alternatives for both on-line transaction processing and on-line analytical workloads. Interpret and comparatively criticize database system architectures.

- Introduction

  - Review Relational Theory Concepts
  - Review Relational Algebra
  - Review SQL Languages
  - History of Data Models and Database Systems

- Physical Storage Systems

  - Overview of Physical Storage Media
  - Storage Interfaces
  - Magnetic Disks

- – Flash Memory

- Data Storage Structures

  - – File Organization
  - – Organization of Records in Files
  - – Data-Dictionary Storage
  - – Database Buffer

- Indexing

  - – Ordered Indices
  - – B$^+$-Tree Index Files
  - – B$^+$-Tree Extensions
  - – Hash Indices

- Query Processing

  - – Measures of Query Cost
  - – Selection Operation
  - – Sorting
  - – Join Operation

- Query Optimization

  - – Transformation of RelationalExpressions
  - – Estimating Statistics of ExpressionResults
  - – Choice of Evaluation Plans
  - – Materialized Views
  - – Advanced Topics in QueryOptimization

- Transactions

  - – Transaction Concept
  - – Transaction Atomicity and Durability
  - – Transaction Isolation
  - – Serializability
  - – Implementation of Isolation Levels

- Concurrency Control

  - – Lock-Based Protocols
  - – Deadlock Handling
  - – Multiple Granularity
  - – Timestamp-Based Protocols
  - – Validation-Based Protocols
  - – Multiversion Schemes
  - – Snapshot Isolation
  - – Weak Levels of Consistency inPractice

- – Recovery from deadlock

- Recovery System

  - – Failure Classification
  - – Recovery and Atomicity
  - – Recovery Algorithms
  - – Buffer Management
  - – Failure with Loss of Non-Volatile Storage
  - – High Availability Using Remote Backup Systems
  - – Early Lock Release and Logical Undo Operations
  - – ARIES

- Database-System Architectures

  - – Parallel Systems
  - – Distributed Systems
  - – Cloud-Based Services

- Parallel and Distributed Storage

  - – Data Partitioning
  - – Dealing with Skew in Partitioning
  - – Replication
  - – Parallel Indexing
  - – Distributed File Systems
  - – Parallel Key-Value Stores

- Parallel and Distributed Query Processing

  - – Parallel Sort
  - – Parallel Join
  - – Parallel Evaluation of Query Plans
  - – Query Processing on Shared-Memory Architectures
  - – Query Optimization for Parallel Execution
  - – Parallel Processing of Streaming Data
  - – Distributed Query Processing

- Parallel and Distributed Transaction Processing

  - – Distributed Transactions
  - – Commit Protocols
  - – Concurrency Control in Distributed Databases

**Main References:** Our Lectuers are mainly based-on this book.

- Abraham Silberschatz, Henry F. Korth, S. Sudarshan, *Database System Concepts*, McGraw-Hill, 7th ed, 2020.

**Supplementary References:** We also use these references for complementary discussion.

- Goetz Graefe, *On Transactional Concurrency Control*, Morgan & Claypool, 2019.

- M. Tamer Ozsu, Patrick Valduriez, *Principles of Distributed Database Systems*, Springer, 4th ed, 2020.

- Gerhard Weikum, Gottfried Vossen, *Transactional Information Systems Theory, Algorithms, and the Practice of Concurrency Control and Recovery*, Morgan Kaufmann, 2001.

- Jim Gray, Andreas Reuter, *Transaction Processing: Concepts and Techniques*, Morgan Kaufmann, 1993.

- Philip A. Bernstein, Eric Newcomer, *Principles of Transaction Processing*, Morgan Kaufmann, 2nd ed, 2009.

- Sam S. Lightstone, Toby J. Teorey, Tom Nadeau, *Physical Database Design: The Database Professional's Guide to Exploiting Indexes, Views, Storage, and More*, Morgan Kaufmann, 4th ed, 2007.

- Nicolas Bruno, *Automated Physical Database Design and Tuning*, CRC Press, 2011.

**Useful Links:** Courses with Video Lectures.

- CMU 15-445/645 Database Systems, Carnegie Mellon University, Fall 2021.

- CMU 15-445/645 Database Systems, Carnegie Mellon University, Fall 2019.

- CMU 15-445/645 Database Systems, Carnegie Mellon University, Fall 2018.

- CMU 15-445/645 Database Systems, Carnegie Mellon University, Fall 2017.

- CMU 15-721 Advanced Database Systems, Carnegie Mellon University, Spring 2020.

- CMU 15-721 Advanced Database Systems, Carnegie Mellon University, Spring 2019.

- CMU 15-721 Advanced Database Systems, Carnegie Mellon University, Spring 2018.

- CMU 15-721 Advanced Database Systems, Carnegie Mellon University, Spring 2017.

- CMU 15-721 Advanced Database Systems, Carnegie Mellon University, Spring 2016.

Seminars.

- Vaccination Database Tech Talks Second Dose - 2021.

- Vaccination Database Tech Talks First Dose - 2021.

- Quarantine Database Tech Talks - 2020.

- Hardware Accelerated Database Lectures - Fall 2018.

- Time Series Database Lectures - Fall 2017.

- The Databaseology Lectures - Fall 2015.

- Seven Databases in Seven Weeks - Fall 2014.

- A Celebration of Mike Stonebraker - 2014.

Reasearch Groups in Database Systems.

- Carnegie Mellon Database Group.

- MIT Database Group.

- MIT Data Systems Group.

- UC Berkeley Data Systems and Foundations.

- Stanford Infolab Group.

- University of Washington's database group.

- UW-Madison Database Group.

- Database of Databases

Books website.

- Database System Concepts.

Our passed Semesters Audio Lectures.

- 7232 Principles of Database Design, IAU South Tehran Branch, Fall 2018.

- 7232 Principles of Database Design, IAU South Tehran Branch, Spring 2017.

**Grading Policy:**

- Assignments (40%)

- Quiz (30%)

- Final Exam (30%)

- (Optional) Presentation (10%)