Announcements

- Webquiz 7 due date extended to tomorrow
- Extra office hours tonight 6pm to 8pm on 4th floor CSE

Final Exam

- Thursday, Dec 13 2:30 - 4:20
- This room
- Closed books, no phones, no computers
- Allowed 2 pages of notes (both sides of each)
- Primary focus on the second half

Course Topics

1. Relational Data
2. Database Design & Implementation
3. Concurrency and Transactions
4. Semi-structured Data
5. Parallel Big Data Systems

When to Use a Database

- Of all the tools we know, how do pick?
- Depends on use case and role
- Easier to implement in database first than reverse engineer

Role: Scientist

- Data type: single csv file
  - Probably don’t need database unless you love SQL
- Data type: many small csv files
  - Good time to use SQLite, easier to add data to one place
- Data type: multiple table catalog
  - Consider more powerful database like PostgreSQL or SQL Server

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Role: Industry Data Analyst

- Very small company: see scientist case
  - Will have to think about database design
- Large company: definitely need database
  - System: whatever they tell you to use
    - Probably the parallel database system de jour (SQL or NoSQL)
  - Often very concerned with speed
    - Can take hours to run a query

Role: Industry Application Developer

- Database design
  - Single node or parallel database?
  - SQL or NoSQL/MapReduce?
  - Indexes
- Making app work with database
  - Transactions
  - Query execution

Relational Data

- Tables with schemas
  - First normal form: no nested tables
  - types for attributes
  - primary and foreign keys
  - other constraints
- bag semantics

1a. Relational Data Model

1b. Relational Queries

- Relational query = expressible in standard RA
- Simple SELECT-FROM-WHERE with no joins or aggregates is:
  - Expressible with nested-loop semantics
  - Always monotone
- Datalog adds recursion

SQL

- CREATE TABLE ... WITH PRIMARY KEY, FOREIGN KEY
  - Constraints UNIQUE, NOT NULL
- CREATE [CLUSTERED] INDEX ... ON ...  
- INSERT INTO ...
- UPDATE ... SET ... WHERE ...
- DELETE FROM ... WHERE ...
SQL (cont.)

- SELECT …
  - JOINs: inner vs outer, natural
  - GROUP BY, sum, count, avg, etc.
  - ORDER BY
- BEGIN TRANSACTION
- COMMIT / ROLLBACK

2a. DB Design Process

2a. DB Design Process

- Constraints
  - key, referential & other constraints
- Normalization
  - Eliminates anomalies
    - redundancy, update, and deletion anomalies
    - Occur from “bad” functional dependencies (FDs that aren’t superkeys)
    - Apply BCNF decomposition to remove them

2a. DB Design Process

- E/R Diagrams
  - Entity sets, relations, & subclasses
  - Map each to relations
    - multiple ways to do this (many-many, one-many)
  - Design principles:
    - model accurately
    - neither too few nor too many entities

3-Tiered Architecture

Database
Design & Implementation
2a. Storage & Indexing
• B+ tree & hash indexes
  – B+ tree index is sorted, best for range queries
• clustered vs unclustered
  – clustered always speeds up query but only one index per table can be clustered
  – unclustered only speed up selections if <1% tuples match

3b. Query Optimization
• main cost is disk access
• many logical plans, many physical plans
  – logical plans are RA expressions with desired result
  – physical plans include e.g. choice of join algorithm
    • E.g. block nested loop join and index nest look join
• cost of many operations depends on selectivity
• optimization problem is hard
• realistic goal is to avoid really bad plans

4c. Transactions
• goal to allow many clients to run simultaneously
  – OLTP workload: lots of clients with small read/writes
• need to provide ACID properties
  – Atomic
  – Consistent
  – Isolated
  – Durable

Concurrency and Transactions

4c. Transactions II
• isolation achieved through serializable schedules
  – serializable means same behavior as a serial schedule
  – conflict serializable means non-conflicting read/writes can be swapped to make schedule serial
    • stronger than (so implies) serializable
• locks ensure conflict serializability if 2PL used
4c. Transactions III
- 2PL: all locks proceed unlocks
- Strict 2PL: must do all unlocks at commit/rollback time
  - needed for isolation if txns can roll back
- need more to prevent phantom rows
  - phantom is a new row that shows up in a table
  - predicate locks are one solution (but expensive)
- default isolation level is usually not serializable
  - faster perf but harder to write app (i.e., bugs likely)

Semistructured Data

4a. Semistructured Data Model
- tree structured data: JSON, XML, etc.
- data is self-describing
  - so schema is not necessary
- easy to map relation to JSON but not opposite

Systems for Big Data

5a. NoSQL Systems
- goal to support heavy OLTP workloads
- provides simplified data model
  - key-value pairs, documents, or extensible records
- limited support for transactions
  - usually pair/document/record level
  - (some support for record groups… all on one node)

5b. Parallel Processing Systems
- for OLAP workloads (big reads, no txns)
- Goal is linear speed up or scale up
- MapReduce
  - programming model is one-to-many map function,
    shuffle sort (grouping), one-to-many reduce function
  - no built-in RA operators
  - stores intermediate data on disk
  - deals with stragglers by running backup map tasks
5c. Parallel Relational Databases

- Partition data across nodes (hash, range, etc.)

- Query evaluation
  - only one new element: reshuffle
    - move tuples to nodes based on values in certain columns
    - basically same as shuffle sort of MapReduce
    - use to implement all extended RA operations
  - new problem: skewed data

Things NOT on the final exam

- Datalog
- SQL++ queries (but there will be NoSQL conceptual questions)
- Join algorithms that were not in the slides
  - (no sort-merge joins but yes nested loop join)
- The difference between B+ tree vs. Hash indexes, can always assume B+ tree
- Isolation levels
- Writing Java code