Database Systems
CSE 414

Lecture 29: Final Review

Announcements

- HW8 due tonight 11pm

Final Exam

- Next Thursday, Dec. 14th, 2:30-4:20
- This room
- Closed books, no phones, no computers
- Allow 2 pages of notes (both sides, 8+pt font)
  - but focus of the test will not be memorization

Course Topics

1. Relational Data
2. DB Applications: Design & Implementation
3. Semi-structured Data
4. DBMS Implementation
5. Big Data Systems

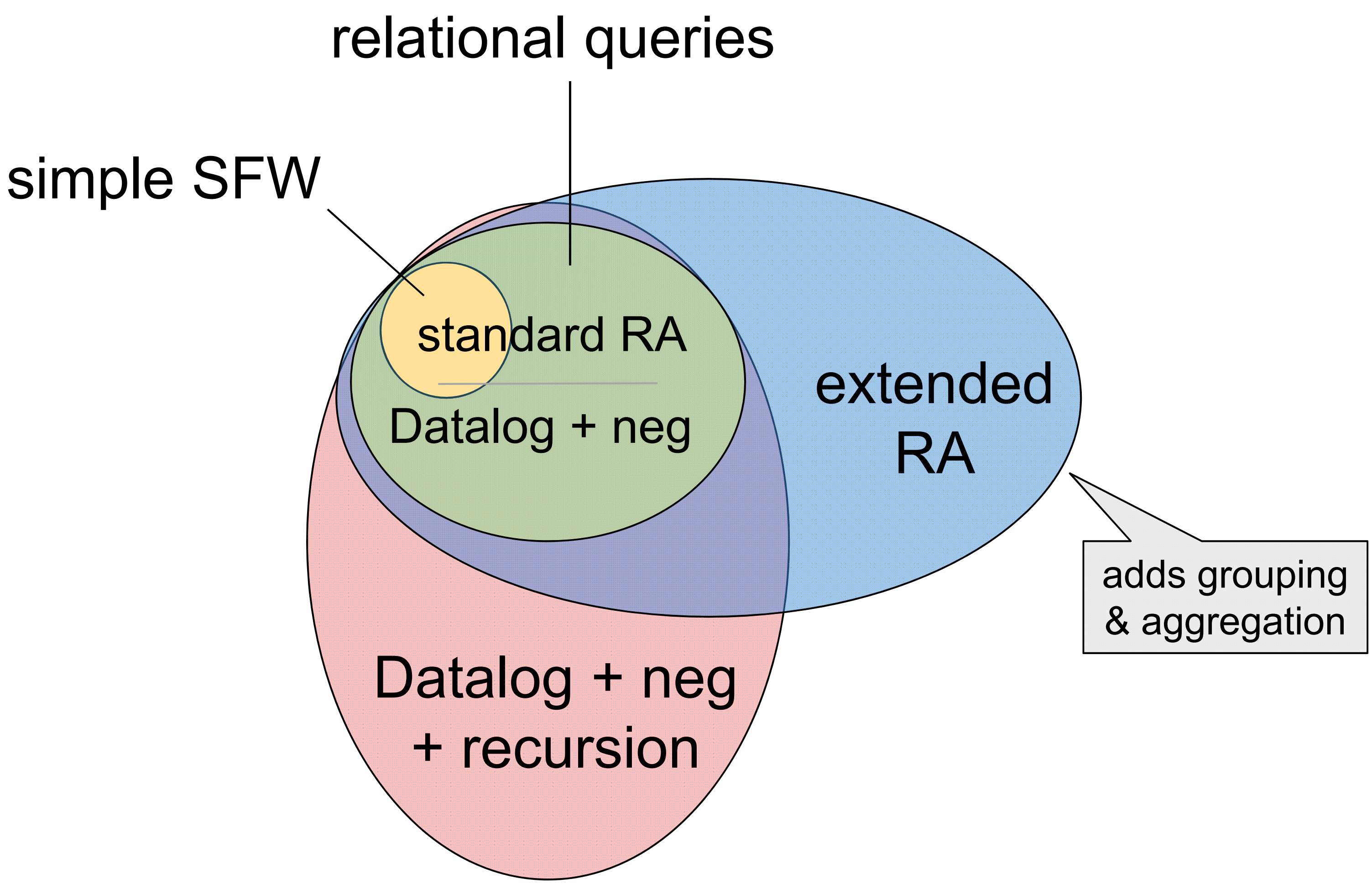
Relational Data

1a. Relational Data Model

- tables with schemas
  - types for attributes
  - primary, secondary, and foreign keys
  - other constraints
- set semantics
  - each tuple is either in the table or not

1b. Relational Queries

- relational query = expressible in standard RA
  - RA = Datalog+neg, also expressible with SQL
- simple SELECT-FROM-WHERE is a subset
  - includes joins, but not subqueries
  - always monotone, while RA isn't (e.g. set difference)
- extended RA adds grouping & aggregation
  - (also uses bag semantics)
- Datalog adds recursion


relational queries
simple SFW
standard RA
Datalog + neg
extended
RA
adds grouping
& aggregation
Datalog + neg
+ recursion

1c. Datalog

- data comes from **facts** and **rules**
  - $P(a_1, \ldots, a_n)$.
  - $Q(a_1, \ldots, a_n)$:- $R1(a_i, b_k, \ldots)$, $R2(a_j, b_l, \ldots)$, ...
- head is a fact iff there is *some* way to set b_k's so that all terms in the body are facts
  - variables only appearing in body (b_k's) are *existential*
- can be translated to SQL
  - must be possible, as Datalog is equivalent to RA
  - but we didn't discuss the details…

DB Applications:
Design & Implementation

2a. DB Design Process

Conceptual Model:

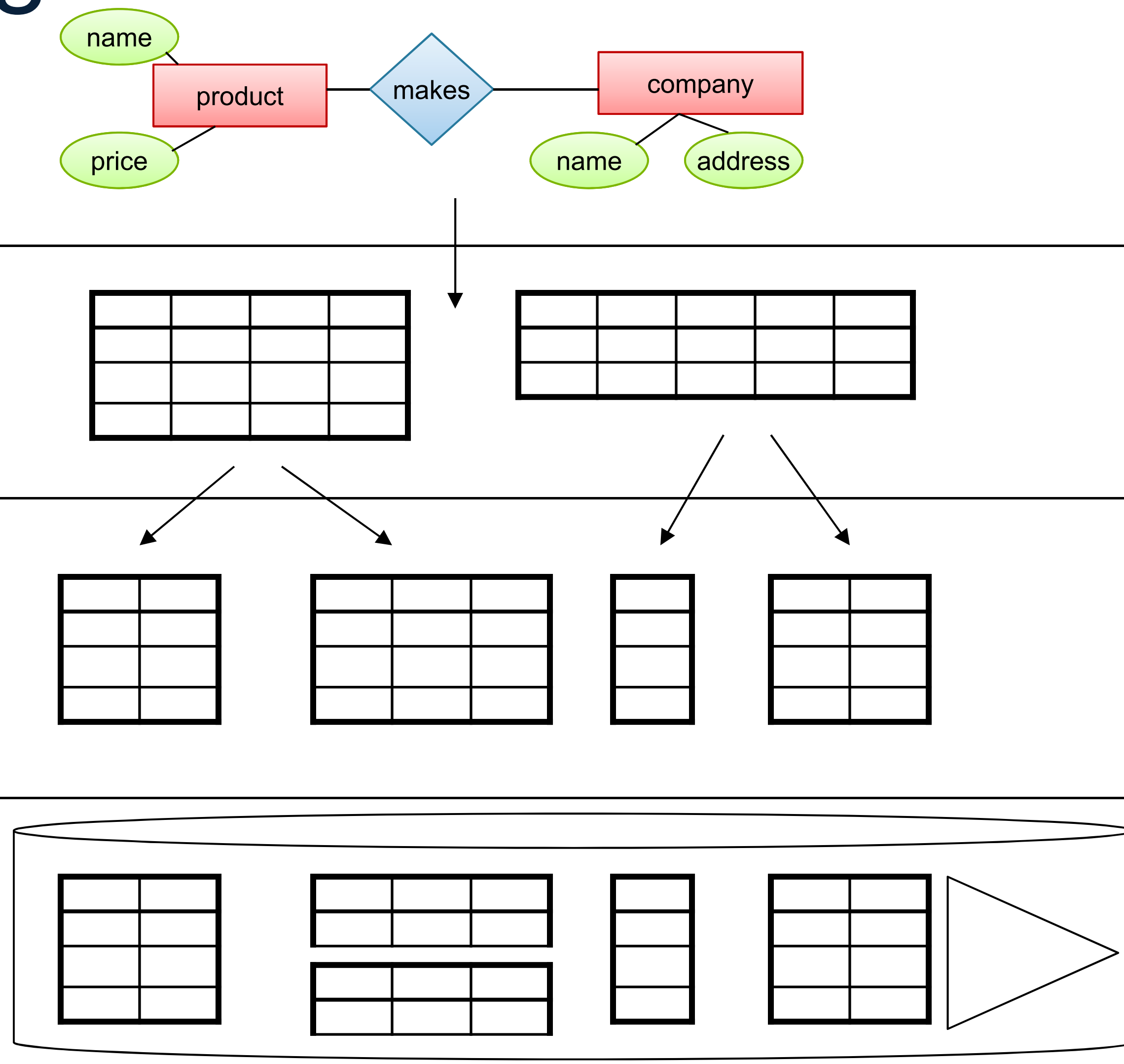
Relational Model:
Tables + constraints
And also functional dep.

Normalization:
Eliminates anomalies

Conceptual Schema

Physical storage details

Physical Schema



2a. DB Design Process

- E/R Diagrams
  - (weak) entity sets, relations, & subclasses
  - map each to relations
    - multiple ways to do this…
      only need to know the approach from class
  - design principles:
    - model accurately
    - neither too few nor too many entities

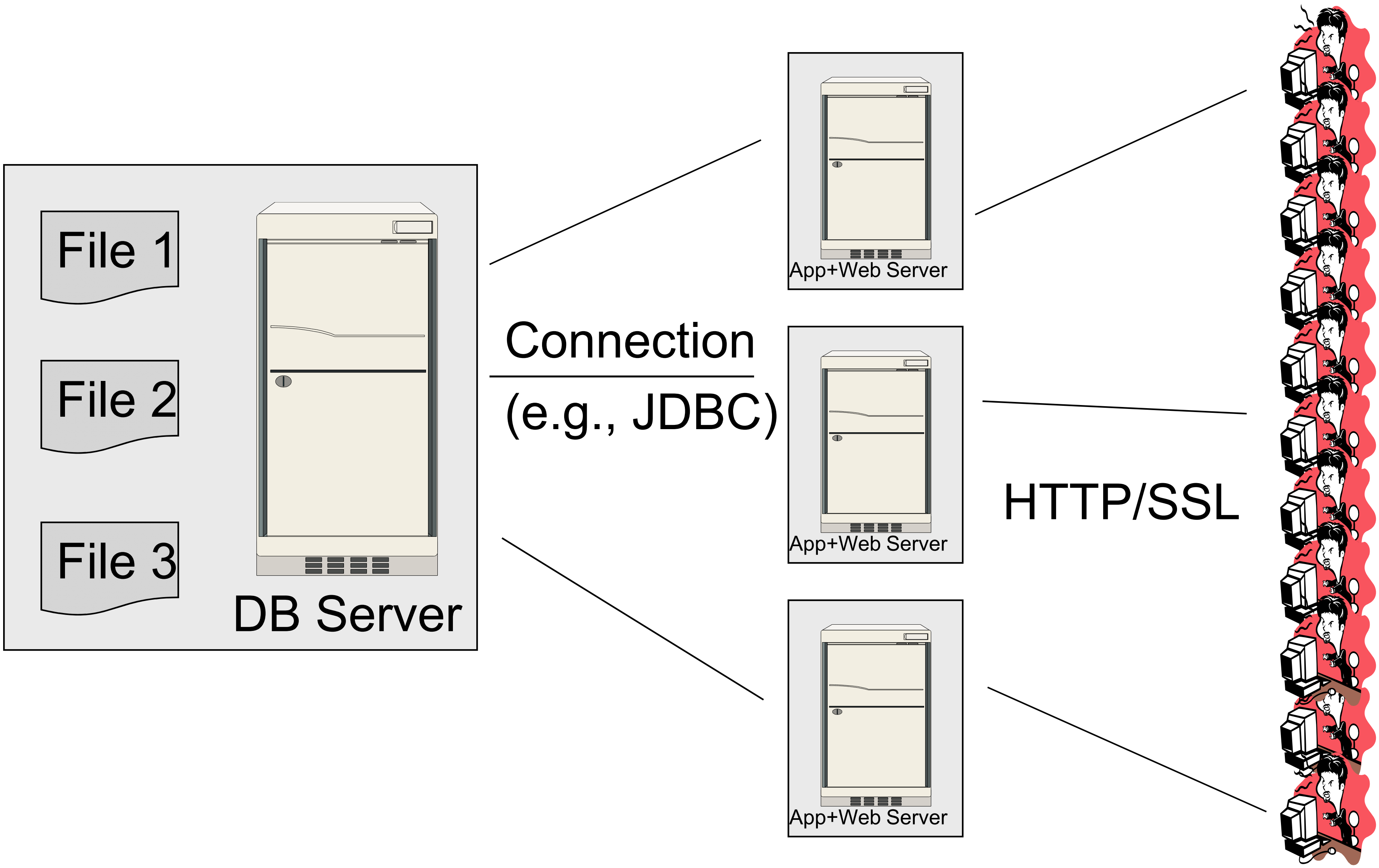
2a. DB Design Process

- Constraints
  - key, single-value, referential & other constraints
    - other includes, e.g., positivity and non-null constraints
- Normalization
  - eliminates anomalies
    - redundancy, update, and deletion anomalies
  - are indicated by “bad” functional dependencies
  - apply BCNF decomposition to remove them
    - these decompositions are never lossy (others can be)

2b. DB Application Implementation

- JDBC
  - connect to DB from Java
  - send SQL statements
  - use transactions
- 3-tiered architecture for web applications

3-Tiered Architecture



2b. DB Application Implementation

- JDBC
  - connect to DB from Java
  - send SQL statements
  - use transactions
- 3-tiered architecture for web applications
  - usually JSON data between web server & browser/phone
  - why not use JSON to the DB too?
    - otherwise, we need to translate JSON to relational

Semi-structured Data

3a. Semi-structured Data Model

- tree structured data: JSON, XML, etc.
- data is self-describing
  - so schema is not necessary
- can choose amount of structure (in AsterixDB)
  - partial constraints on shape of data
  - open vs. closed types
- NFNF data
  - could put entire data in one row (mondial)
- easy to map relation to JSON, but not opposite

3b. Semi-structured Queries

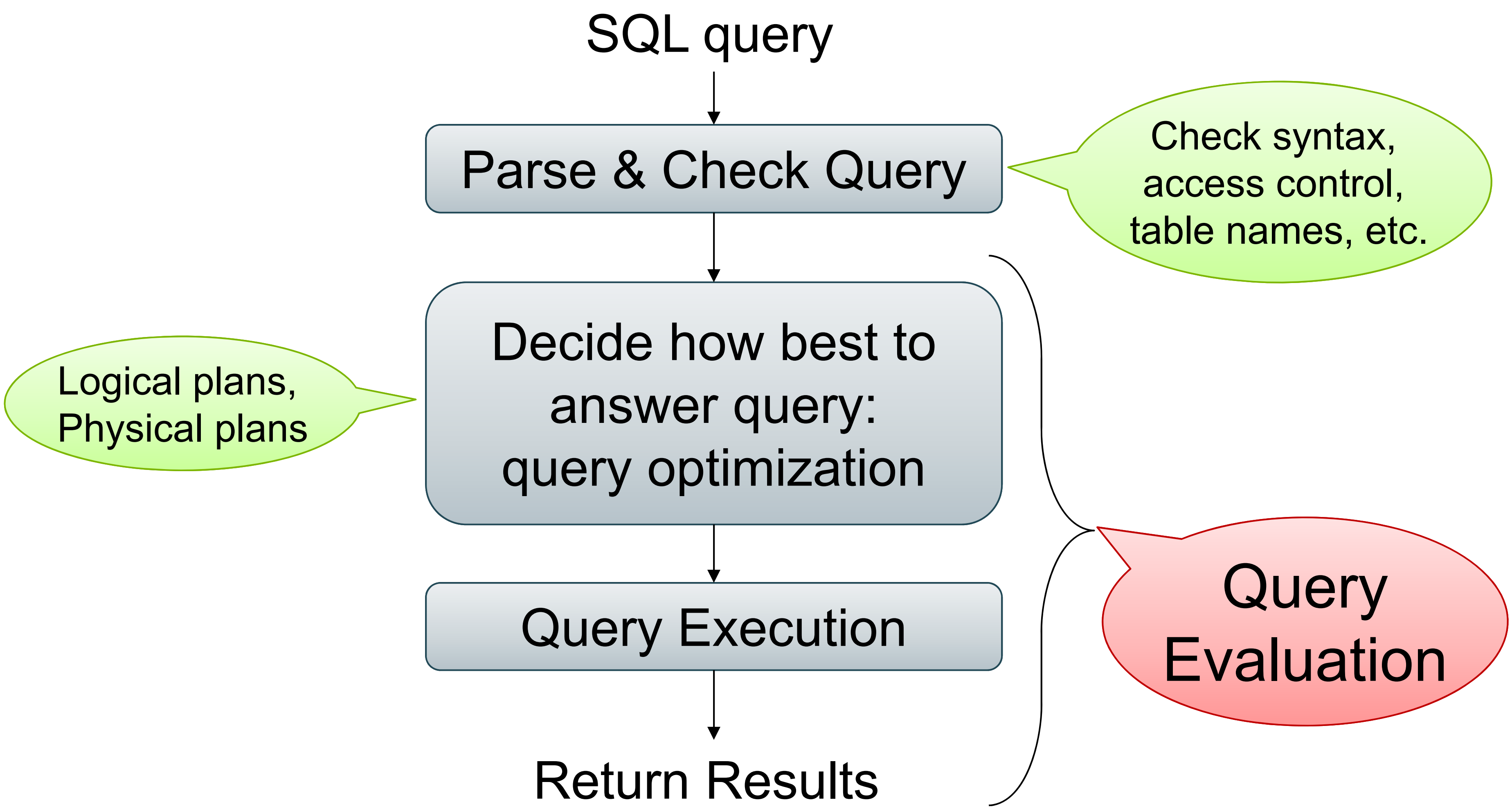
- new concepts
  - **unnesting**: join with contents of list-valued column
  - **nesting**: make list from results of subquery
  - each is a new operator for logical query plans
- dealing with heterogeneous data needs work
  - often CASE WHEN … for different types
  - requiring more structure makes queries easier, but adding data becomes harder
    - (this work has to be done somewhere)

DBMS Implementation

4a. Storage & Indexing

- B+ tree & hash indexes
  - B+ tree index allows searching by key prefixes also
- understand when an index can be used
  - (separate question from whether it improves performance)
- clustered vs. unclustered
  - clustered always speeds up query,
    but only one index per table can be clustered
  - unclustered only speeds up if <1% tuples match

Query Evaluation Steps



4b. 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
    - hash, sorted merge, and (block refined) nested loop joins
- cost of many operations depends on selectivity
- optimization problem is hard
  - saw SQL Server does poorly in homework problems
- 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: execute all SQL statements or none
  - consistent: finish with all constraints satisfied
  - isolation: behavior same as if one-at-a-time use
  - durable: committed result are permanent (‘til changed)
- consistency maintained by checking constraints
- durability maintained by writing to disk(s)

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
  - multiple read locks, only one write lock
    - becomes 4 types in SQLite (a good design)
  - lock granularity from (parts of) rows to tables to DB
  - …

4c. Transactions III

- strict 2PL: no unlocks before commit/rollback
  - needed for isolation if txns can roll back
- can produce deadlocks (as seen in homework)
- need more to prevent phantom rows
  - phantom is a new row that shows up in a table
  - predicate locks are one solution (but expensive)

- multi-version concurrency control is alternative
- default isolation level is usually not serializable
  - faster perf but harder to write app (i.e., bugs likely)

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)
- partition data across nodes for scale
- replicate data to survive node failures

5b. Parallel Processing Systems

- for OLAP workloads (big reads, no txns)
- MapReduce
  - programming model is one-to-many *map* function, shuffle sort (grouping), one-to-many *reduce* function
  - no built-in RA operators
    - but easy to implement, as shuffle sort is provided
  - stores intermediate data on disk
    - reasonable if input/output is also to disk (otherwise too slow)
  - deals with stragglers by running backup map tasks

5b. Parallel Processing Systems II

- Spark/Scala
  - executes a dataflow pipeline using many nodes
  - Google Dataflow & Hyracks (AsterixDB) do same
    - each provides extended RA operators
  - Spark handles failure by re-computing, not replicating
- Spark SQL
  - map SQL ~> extended RA ~> dataflow pipeline
  - same approach can be used on any dataflow engine

5b. Parallel Processing Systems III

- Existing systems do not optimize well
  - none does real cost-based optimization
  - Spark only performs small, syntactic optimizations
    - one exception: choice of parallel vs. broadcast join
  - Spark has no indexes
  - AsterixDB has indexes, but no statistics
  - all require manual tuning
    - saw this with AsterixDB on homework
- PageRank

5c. Parallel Databases

- support both OLTP and OLAP
- goal: more nodes => faster or allow more data
  - speed up or scale up
- different architectures
  - shared memory (SQL Server etc.): limited scale
  - shared disk (mostly Oracle): limited scale
  - shared nothing: really scales (so our focus)
    - won out in academic research (started in 1980s)
    - basis for parallel processing systems (see previous slides)

5c. Parallel Databases II

- 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
  - linear speed up or scale up in principle
  - in practice, stragglers are a problem (MapReduce tries to discover and redo the tasks the stragglers are working on)
  - new problem: skewed data
    - may not all fit in memory of one node

5c. Parallel Databases III

- AsterixDB is the closest we have seen to this
  - came out of parallel DB community
  - executes OLAP queries as in parallel processing
  - but only has record-level transactions as in NoSQL
    - (more OLTP than parallel processing systems though)
- More complete systems in the near future
  - see also Google Spanner, Microsoft Cloud DB

SQL (Everywhere)

5. SQL

- CREATE TABLE …
  - PRIMARY KEY, UNIQUE, FOREIGN KEY
  - CHECK (constraints) on columns or tuples
- CREATE [CLUSTERED] INDEX … ON ...
- INSERT INTO …
- UPDATE … SET ... WHERE ...
- DELETE FROM ... WHERE …

5. SQL (cont.)

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