Engineering Robust Server Software

Scalability

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Other Scalability Issues

- Database
- Load Testing

Databases

- Most server applications use databases
  - Very complex pieces of software
  - Designed for scalability
- …but how well depends on what you are doing with them…

First Question: DB or in Your Program?

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- Do you do computation in DB or in your own code?
  - Tradeoffs
    - Code to write/test
    - Costs of consistency
    - IO costs / stored data
- Might be good to mix the two
  - E.g., hwk4 you might store transactions in db, but match in memory

Databases and Concurrency

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- How do databases handle concurrency?
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- Postgres (and many others): MVCC
  - Multi-version concurrency control
  - Basically, the DB keeps multiple versions
  - Ensures **consistency** based on **transaction isolation level**

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  - Who can remind us what it is?
  - What are its benefits?

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- In 650, you learned about serializability…
  - Who can remind us what it is?
  - What are its benefits?
- Does this sound similar to any other ideas we have learned recently?
  - If so, what conclusions might you draw about performance?
  - What do you think we might do?

Isolation Levels

- Serializable
  - As in 650
  - Nothing unexpected
- Repeatable Read
  - Can have **phantom reads**
- Read Committed (default in Postgres)
  - Can have **non-repeatable reads** (+phantoms)
- Read Uncommitted
  - Can have **dirty reads** (+non-repeatable +phantoms)

Non-Repeatable Read

id	count
42	66
67	128
99	0
456	1

Values within a row change between reads

SELECT count from tbl WHERE id = 42;

99

UPDATE tbl SET count = 66 WHERE id = 42;
COMMIT;

SELECT count from tbl WHERE id = 42;

66

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Phantom Read

id	count
42	66
67	128
99	32
456	1

Set of rows in a query change between reads

SELECT * from tbl WHERE count < 10;

(99,0)
(456,1)

SELECT * from tbl WHERE count < 10;

(456,1)

UPDATE tbl SET count = 32 WHERE id = 99;
COMMIT;

Dirty Read

id	count
42	66
67	128
99	32
456	77

Read from uncommitted transaction

UPDATE tbl SET count = 77 WHERE id = 456

SELECT count from tbl WHERE id = 456;

77

ROLLBACK;

Isolation Levels: Postgres

- Serializable — Can throw exns for violations
  - As in 650
  - Nothing unexpected
- Repeatable Read — Can throw exns for violations
  - Can have **phantom reads**
- Read Committed (default in Postgres)
  - Can have **non-repeatable reads** (+phantoms)
- Read Uncommitted — Not actually available: upgraded to Read Committed
  - Can have **dirty reads** (+non-repeatable +phantoms)

More On Isolation

- For more on isolation in Postgres, see
  - https://www.postgresql.org/docs/9.5/static/transaction-iso.html

Query Performance

- Many things can affect query performance
  - Complicated topic..
- But how can you gain insight into what is going on?
- Can you do anything to improve it?

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- But how can you gain insight into what is going on?
- Can you do anything to improve it?
  - First thing we always want to do?

Understand Behavior: Explain

```
explain select * from grades where grade <62;
                        QUERY PLAN
-----------------------------------------------------------
 Seq Scan on grades  (cost=0.00..494.80 rows=55 width=35)
   Filter: (grade < 62)
```

Startup Cost

Total cost (arbitrary units)

- Want to know how your query is going to be executed?
  - Ask Postgres to EXPLAIN it
  - https://www.postgresql.org/docs/9.5/static/sql-explain.html

Seq Scan?

- Sequential Scan = linearly examine each element.
  - Sound good?

Seq Scan?

- Sequential Scan = linearly examine each element.
  - Sound good?
- No! We can do better..
- How?
  - Ask postgres to build an index `CREATE index ON grades (grade);`

```
explain select * from grades where grade <62;
                                QUERY PLAN
-----------------------------------------------------------------------
Bitmap Heap Scan on grades  (cost=4.71..128.27 rows=55 width=35)
   Recheck Cond: (grade < 62)
   ->  Bitmap Index Scan on grades_grade_idx  (cost=0.00..4.70
rows=55 width=0)
         Index Cond: (grade < 62)
```

Indexes

- Why not index everything?
  - Cost to maintain index
  - Building=expensive: do before deploying
- Build indexes that are useful for the queries you need
- See
  - https://www.postgresql.org/docs/9.5/static/sql-createindex.html

NoSQL

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  - …

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- Wide variety of databases that don't do SQL
  - Key-value stores
  - Graph-based
  - …
- Many make tradeoffs to increase scalability
  - Eventual Consistency—may not get most current data
    - CAP theorem
  - Accept possibility of data loss
  - …

Load Testing

- All of this discussion of scalability..
  - How do we know how well we are doing?
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  - What is a successful test case?

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- Test your code!
  - What is the purpose of testing? Discover problems
  - What is a successful test case? One that shows a problem
- So for load testing, what is our criteria for success?
  - Identify performance/scalability problems

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  - Why?

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  - Does indexing matter? Yes
  - What level of the memory hierarchy do you hit? Disk
- How different are these performance characteristics?
  - Bandwidth?
  - Latency?

Load Testing

- **Rule 1**: generate a lot of load
  - Sending one request, then another serially? Not enough
  - Need multiple programs/threads/systems generating load
- **Rule 2**: system needs significant data to start
  - Performance characteristics depend on size
- **Rule 3**: data needs to have reasonable characteristics
  - Match values/conditions on values of real data
  - Why?

Data Must Be Realistic

- Suppose you run the query
  - SELECT * from whatever WHERE x < 100 AND x > 50;
  - You have only 5 in that range in your test data
  - Your real data ends up with 5,000,000 in that range
- How similar will your performance characteristics be?

Load Testing

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- **Rule 3**: data needs to have reasonable characteristics
  - Match values/conditions on values of real data
- **Rule 4**: mix and match many combinations of operations in parallel
  - Why?

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Mix and Match Operation

- Obvious: we want to ensure each operation done at least once
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- Obvious: we want to ensure each operation done at least once
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  - Different resource usage: cache, bandwidth, ….
  - Different pairings = different resource contention
    - And different DB contention
    - Read by itself vs waiting for a write to commit

What Is "Passing"?

- Ok, so you follow all my rules…
- Make your test cases…
- Run them….
- How do you know if you "passed" the test?

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- Ok, so you follow all my rules…
- Make your test cases…
- Run them….
- How do you know if you "passed" the test?
  - …It depends…. (oh man, I love that answer).

Different Goals

- We might have different goals:
  - Can our system handle the demand from X users?
    - e.g., can DukeHub handle registration?
  - Did we just make it better?
    - e.g., we think we optimized the code, did it really improve?
  - Does our system scale sufficiently with more hardware?
    - Note: requires definition of "sufficiently"
  - Does our system degrade gracefully with more load?
    - Note: requires definition of "gracefully"

Can We Handle Demand of X Users

- Load test with loads that try to mimic X Users
  - May not be hitting system as hard as you possibly can
  - Probably want to add some margin for error
- Measure latencies of requests
  - See how many are within tolerable range
    - Define tolerable?
  - Quite possibly in terms of % guarantees
    - e.g., 99% of requests took less than 500 usec.

Did We Make It Better?

- You do something to your code to improve scalability
  - (Add an index, replace a locked DS with a LF one, …)
  - How do you know it is actually better?
    - Side note: how do you convince your boss that
      - (a) it was worth your time
      - (b) he/she should give you a raise for your hardcore hacking?

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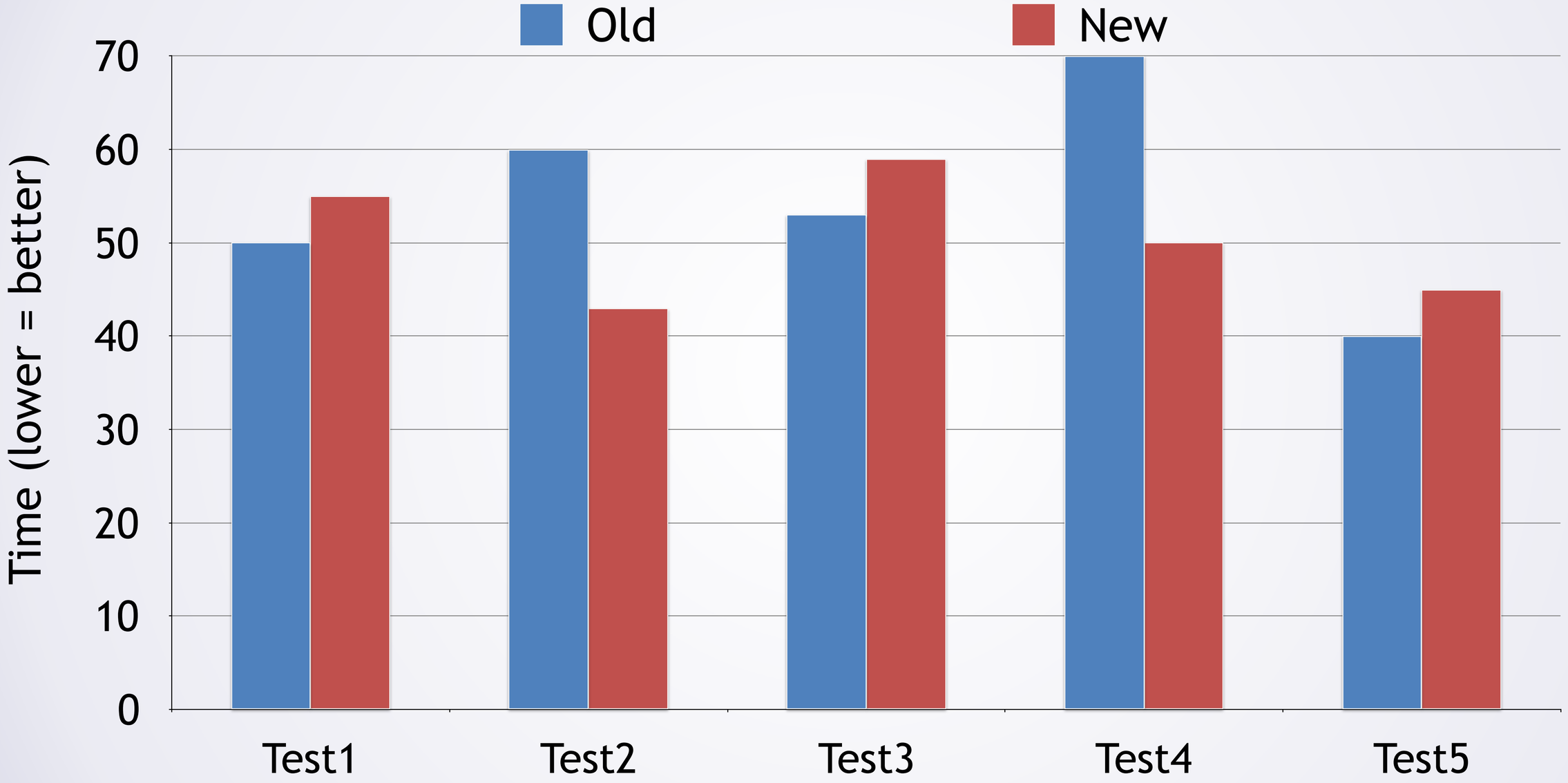
  - How do you know it is actually better?
  - Run the old, run the new, measure performance -> see which wins
    - Is it that simple?

Did We Make It Better



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  - How do you know it is actually better?
  - Run the old, run the new, measure performance -> see which wins
    - Different tests may show different results
    - Different metrics may show different results
      - E.g., slower with this hw, but more scalable with more hw

Is Our System Scalable "Enough"?

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  - That also depends…

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  - Combines two notions of scalability we saw earlier
  - Why does this make business sense?

Is Our System Scalable "Enough"?

- What is scalable enough?
  - That also depends…
- How much hardware do we need to add for X more users?
  - Combines two notions of scalability we saw earlier
  - Why does this make business sense?
    - Compute costs money, users bring money -> profitable?
    - Think Cloud Computing

Wrap Up

- Today
  - Databases
  - Load Testing
- Next Week:
  - Begin guest lectures