CS428: Software Engineering II

Performance

Slides are modified based on Cosmin Radoi's slides for Spring 2014

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Arnold Allen

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Good performance =

- high speed, or high throughput
- good responsiveness (short response time)
- low energy consumption
- good usability, good ROI, ...

Why optimize for performance?

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- *soft* performance requirement

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- do NOT optimize during development

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- *soft* performance requirement
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Generally, *when* to optimize for performance?

- do NOT optimize during development
- when a performance need is clearly identified, e.g.,
  - you do alpha testing, and notice regular lags
  - you receive bug reports
  - particular UI/integration tests are slow
  - A/B testing and the results don't add up
  - ...

Some definitions

Throughput (Velocity)

Amount of data processed (computed, transmitted, etc.) in a unit of time.

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Amount of data processed (computed, transmitted, etc.) in a unit of time.

- database transactions per second
- web pages served per second
- data entries computed per second

Some definitions

Response time

Amount of time in which a result is produced.

Some definitions

Response time

Amount of time in which a result is produced.

- amount of time to serve a web page
- amount of time to clear a credit card transaction
- amount of time to get web service response
- ....

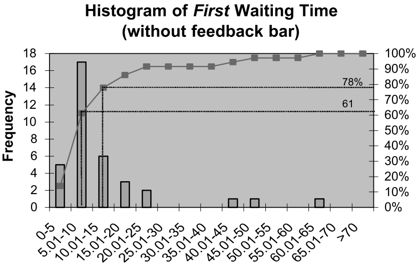
Web response time

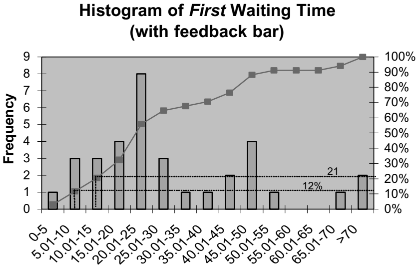
- 0.1s - feels instantaneous
- 1s - no disturbance in the flow of work
- 2s - average waiting time, attention span
- 10s - keep on task

- Palmer, Jonathan W. ”Web site usability, design, and performance metrics.” Information systems research 13.2 (2002): 151-167.
- Nah, Fiona Fui-Hoon. ”A study on tolerable waiting time: how long are web users willing to wait?.” Behaviour & Information Technology 23.3 (2004): 153-163.

Web response time

- progress bars are cheaper than performance optimization





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Pareto principle

- 80% of the effects come from 20% of the causes

Group Discussion

- Get into a group of 2 (or 3 students), share with each other one or two examples of performance faults that you experienced or observed
  - What it was about
  - How you found the performance failure
  - How you diagnosed the failure and hunted out the root cause (fault)
  - How you fixed the fault
- Pick random/sample groups to share their discussion outcome

Pareto principle

- 80% of the effects come from 20% of the causes
- for programs, 80% of the time is spent in 20% of the program

Amdahl's Law

The improvement in performance is limited by the fraction of the overall time used by the optimized part of the system.

E.g., querying the database takes 100ms out of the 300ms required to serve a webpage.
What speedup would you get with a perfect database (which takes 0ms to query)?

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“Old Wives’ Tales” identified in Code Complete

Sources of inefficiency

- multilayer architectures
- high-level languages
- I/O
- bad design decisions
- inappropriate use of data structures
- expensive algorithms

Access time

```
L1 cache reference                              0.5 ns
Branch mispredict                               5 ns
L2 cache reference                              7 ns
Mutex lock/unlock                             100 ns (25)
Main memory reference                         100 ns
Compress 1K bytes with Zippy               10,000 ns (3,000)
Send 2K bytes over 1 Gbps network          20,000 ns
Read 1 MB sequentially from memory        250,000 ns
Round trip within same datacenter         500,000 ns
Disk seek                              10,000,000 ns
Read 1 MB sequentially from network    10,000,000 ns
Read 1 MB sequentially from disk       30,000,000 ns (20,000,000)
Send packet CA->Netherlands->CA       150,000,000 ns
```

Jeff Dean – Designs, Lessons and Advice from Building Large Distributed Systems

Profiling

- starts with or attaches to your running program
- gives detailed information about its resource utilization
- demo VisualVM ...

Low-level tuning

- order tests by frequency
- choose better logic structures
- table lookup instead of boolean logic
- loops
  - unswitching, fusion (jamming), unrolling, reorder loop nest
  - minimize work inside a loop
  - terminate loops early
- use integers instead of floating point
- algebraic identities
- strength reduction
- recode in low-level language

Why NOT do low-level tuning?

- many optimizations are platform dependent
- good compilers are much better than average humans
- *interpreted* languages also benefit - JITs

Caching

Caching

- very powerful
- for the functional programming inclined, same as laziness
- can also be done at compile time - precompute values

Caching example

```
Output compute(Input input) {
    ...
}
```

$$\Downarrow$$

Caching example

```
Output compute(Input input) {
    ...
}
```

⇓

```
Map<> precomputed = new Map<Input, Output>()
private Output eagerCompute(Input input) {
    ...
}
Output compute(Input input) {
    Output output = precomputed.get(input);
    if (output != null) {
        return output;
    } else {
        output = eagerCompute(input);
        precomputed.put(input, output);
        return output;
    }
}
```

CheckRole (temporal)

Cost: 16% of 30% instruction-count overhead

Path:

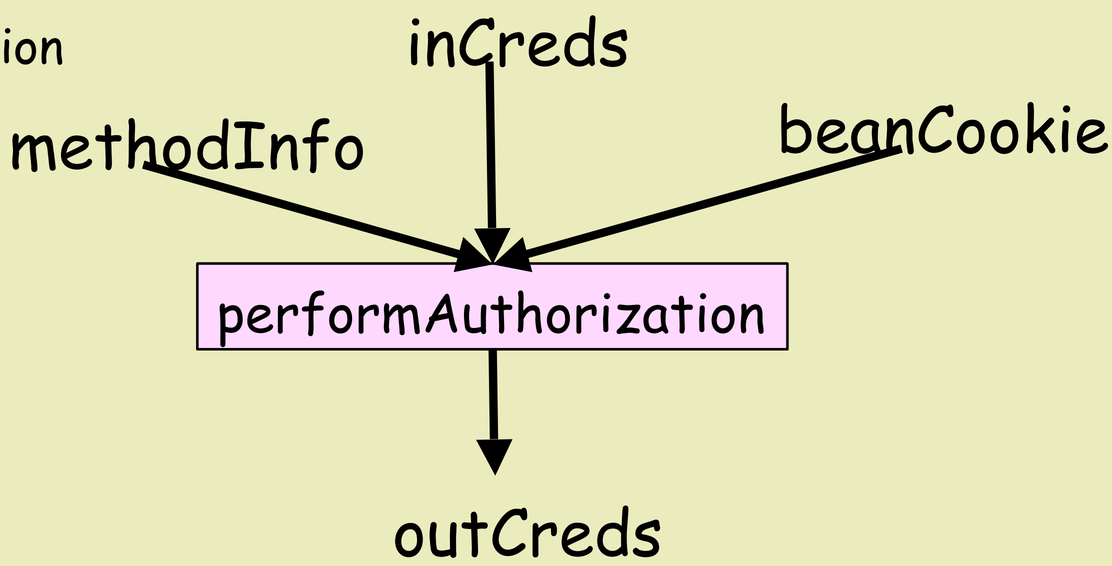
preInvoke

calls performAuthorization

calls ejbCheckAuthorization

calls checkAccess

Observation: decision is (almost) deterministic



CheckRole, optimized with cache

methodInfo inCreds beanCookie

```
performAuthorization
    tbl = getTable(methodInfo)
    if (tbl.hits(inCreds, beanCookie))
        return tbl.value(inCreds, beanCookie)
    else
        creds = compute creds the slow way
        tbl.add(inCreds, beanCookie, creds)
        return creds
```

outCreds

GetCred (spatial)

Cost: 13% of 30% instruction-count overhead

Path:

- preInvoke
- calls doPrivileged
- calls run
- calls get_credentials

```
preInvoke
    doPrivileged // Expensive!
        creds = get_credentials()
    if (!isGrantedAnyRole(roles, creds))
        Scream!

// In another class, far far away
public get_credentials()
    // Expensive!
    stack = getAccessContext()
    checkPermission(stack, canReadCreds)
    return creds
```

GetCred, optimized by specializing

```
private static boolean ok = false;
preInvoke
    if (ok) creds = get_credentialsQuickly()
    else doPrivileged       // Expensive!
                  creds = get_credentials()
    if (!isGrantedAnyRole(roles, creds))
        Scream!

// In another class, far far away
public get_credentials()
    // Expensive!
    stack = getAccessContext()
    checkPermission(stack, canReadCreds)
    ok = true
    return creds
public get_credentialsQuickly()
    return creds
```

- Wide application
- Proposed for IBM JIT

DBReuse

Cost: 10% of 30% instruction-count overhead

Paths:

getConnection
calls <5 methods>
calls doPrivileged
calls <2 methods>
calls Subject.equals

getConnection
calls <2 methods>
calls getSubject
calls doPrivileged

getConnection
calls <7 methods>
calls Subject.hashCode

Optimization:

Cache results of equals(), hashCode(), getSubject()

Reflection

Cost: 25% of 30% instruction-count overhead

Path:

CacheableCommandImpl.execute

calls CacheableCommandImpl.setOutputProperties // uses reflection!

calls doPrivileged

calls run

calls checkMemberAccess

Optimization: avoid reflection by overriding setOutputProperties

Throughput improvements, by optimization