Scalable Internet Architectures

OmniTI / Architecting at Scale

Who am I? @postwait on twitter

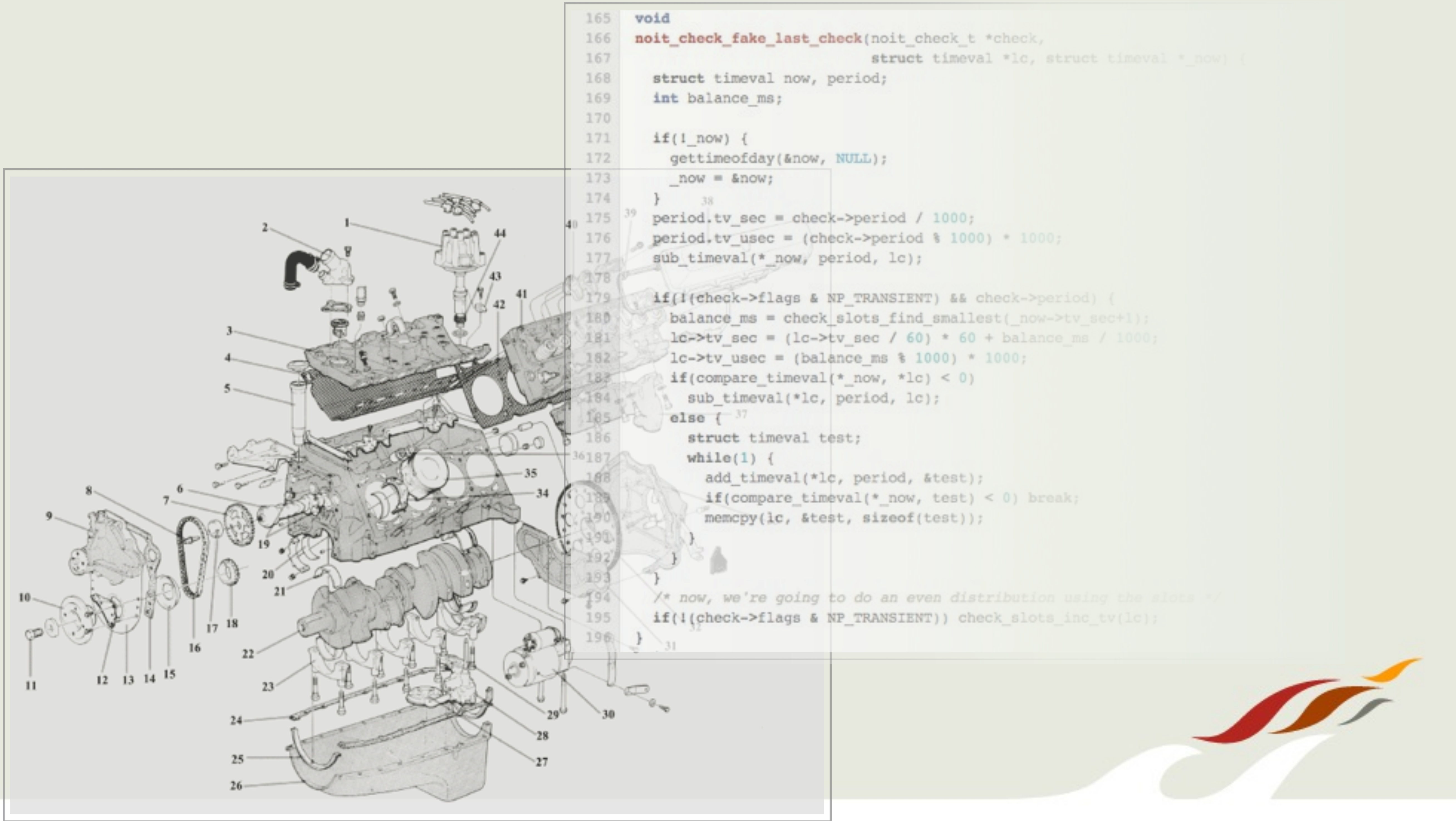
- Author of "Scalable Internet Architectures"
  Pearson, ISBN: 067232699X
- CEO of OmniTI
  We build scalable and secure web applications
- I am an Engineer
  A practitioner of academic computing.
  IEEE member and Senior ACM member.
  On the Editorial Board of ACM's Queue magazine.
- I work on/with a lot of Open Source software:
  Apache, perl, Linux, Solaris, PostgreSQL,
  Varnish, Spread, Reconnoiter, etc.
- I have experience.
  I've had the unique opportunity to watch a great many catastrophes.
  I enjoy immersing myself in the pathology of architecture failures.

Topic Progression

- What is an architecture?
  - What does it mean to run a (scalable) architecture?
  - Measure! Measure! Measure!
- Scalability Patterns for
  - Dynamic Content
  - Databases
  - Complex Systems
  - Networking
- Bad Ideas

Full disclosure

- This workshop will not solve your problems
- Your problems aren't my problems
  (unless you pay me to make them my problems)
- My goals are:
  - to make you think harder about your problems
  - to evaluate possible solutions without bias
  - to motivate you to be a better engineer
- What superpower allows me to do this:
  - deep and strong hatred for all technologies,
    not just a select few.



OmniTI / architecture vs. implementation

Architecture / *what it is*

- architecture (n.):
  the complex or carefully designed structure of something.

  specifically in computing:
  the conceptual structure and logical organization of a computer or a computer-based system.

- Oxford American Dictionary

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Architecture vs. *Implementation*

- Architecture is without specification of the vendor, make model of components.
- Implementation is the adaptation of an architecture to embrace available technologies.
- They are intrinsically tied.
  Insisting on separation is a metaphysical argument (with no winners)

Architecture / *more than meets the eye*

- An architecture is all encompassing.
  - space, power, cooling
  - servers, switches, routers
  - load balancers, firewalls
  - databases, non-database storage
  - dynamic applications
  - the architecture you export to the user (javascript, etc.)

Architecture / *awareness is key*

- Not all people do all things.
- However...
  - lack of awareness of the other disciplines is bad
  - leads to isolated decisions
  - which leads to unreasonable requirements elsewhere
  - which lead to over engineered products
  - stupid decisions
  - catastrophic failures

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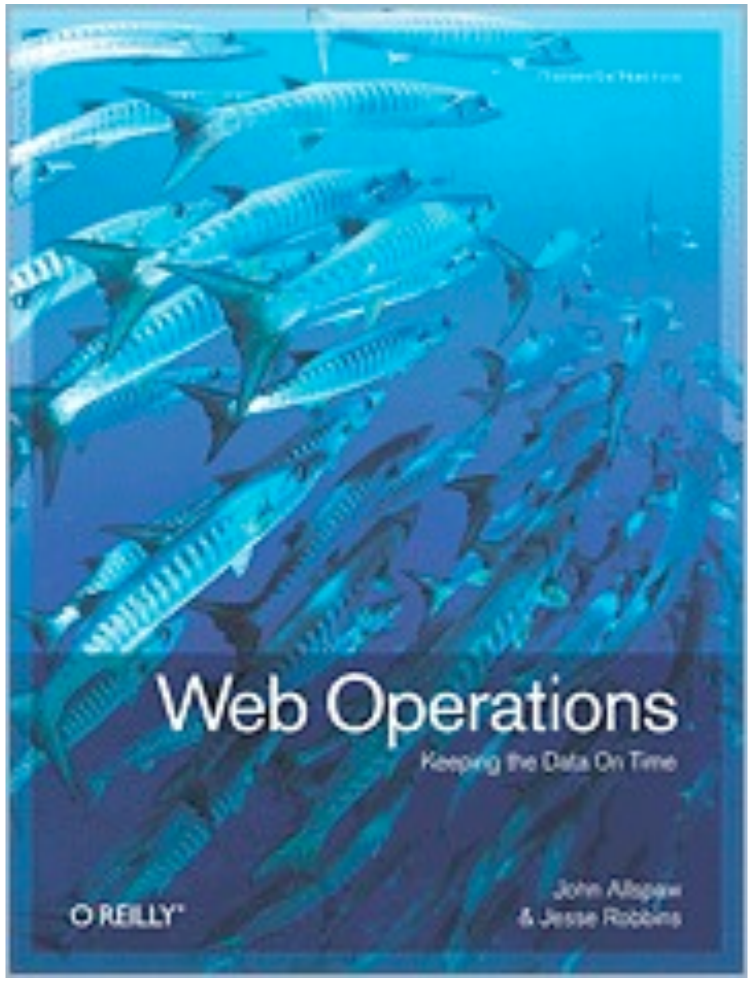
Architecture / *running it all*

- Running Operations is serious stuff
- It takes ***knowledge***, ***tools***...
- but that is not enough.
- It takes ***experience***.
- And perhaps even more importantly...
- It takes ***discipline***.



*"Good judgment comes from experience.
Experience comes from bad judgment."*

- Proverb

*"Judge people on the poise and integrity
with which they remediate their failures."*

- me

Architecture / *know your deployments*

- Everything must always be in version control.
- If you know don't do this, I will kick your ass.
- If you know someone at work that doesn't do this, you can hire me to come kick their ass.

mercurial

git

SUBVERSION

#1 put your shit in version control

Architecture / *know your deployments*

http://www.flickr.com/photos/gcfairch/4385543669/sizes/l/in/photostream/

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- To know when something looks unhealthy,
  one must know what healthy looks like.
- Monitor everything.
- Collect as much system and process information as possible.
- Look at your systems and use your diagnostic tools
  when things are healthy.

Reconnoiter

CIRCONUS
PERFORMANCE MONITORING – REVOLUTIONIZED

Rule / *respect telemetry*

#2 if it's not monitored it's not in production

Computers: How they work.

$$\frac{T_s}{\left(\%S + \frac{1-\%S}{N}\right) \cdot T_s}$$

Basic Arithmetic

$$\begin{array}{r} 7 \\ +4 \\ \hline 11 \end{array}$$

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Image credit: Monty Python

Respect *Engineering Math*

- Engineering math:
  - 19 + 89 = 110
- "Precise Math":
  - 19 + 89 = 10.8

Ok. Ok. I must have, I must have put a decimal point in the wrong place or something. Shit. I always do that. I always mess up some mundane detail.

- Michael Bolton in Office Space

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Insure *the gods aren't angry.*

Bob: *We need to grow our cluster of web servers.*

Alice: *How many requests per second do they do, how many do you have and what is there current resource utilization?*

Bob: *About 200 req/second, 8 servers and they have no headroom.*

Alice: *How many req/second do you need?*

Bob: *800 req/second would be good.*

Alice: *Um, Bob, 200 x 8 = 1600... you have 50% headroom on your goal.*

Bob: *No... 200 / 8 = 25 req/second per server.*

Alice: *Bob... the gods are angry.*

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Why *you've* pissed *of the gods.*

- Most web apps are CPU bound (as I/O happens on a different layer)
- *Typical box today:*
8 cores are 2.8GHz or
22.4 BILLION instructions per second.
- *22×10^9 instr/s / 25 req/s = 880 MILLION instructions per request.*
- *This same effort (per-request) provided me with approximately 15 minutes enjoying "Might & Magic 2" on my Apple IIe - you've certainly pissed me off.*
- *No wonder the gods are angry.*

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Develop *a model*

- Queue theoretic models are for “other people.”
- Sorta, not really.
- Problems:
  - very hard to develop a complete and accurate model for solving
- Benefits:
  - provides insight on architecture capacitance dependencies
  - relatively easy to understand
  - illustrates opportunities to further isolate work

Rationalize *your model*

- Draw your model out
- Take measurements and walk through the model to rationalize it
  i.e. prove it to be empirically correct
- You should be able to map actions to consequences:
- A user signs up ➙
  4 synchronous DB inserts (1 synch IOPS + 4 asynch writes)
  1 AMQP durable, persistent message
  1 asynch DB read ➙ 1/10 IOPS writing new Lucene indexes
- In a dev environment, simulate traffic and rationalize you model
- I call this a "data flow causality map"

Complexity *will eat your lunch*

- there will always be empirical variance from your model
- explaining the phantoms leads to enlightenment
- service decoupling in complex systems give:
  - simplified modeling and capacity planning
  - slight inefficiencies
  - promotes lower contention
  - requires design of systems with less coherency requirements
  - each isolated service is simpler and safer
  - SCALES.

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Rule / *learn math*

#3 always rationalize your inputs and outputs

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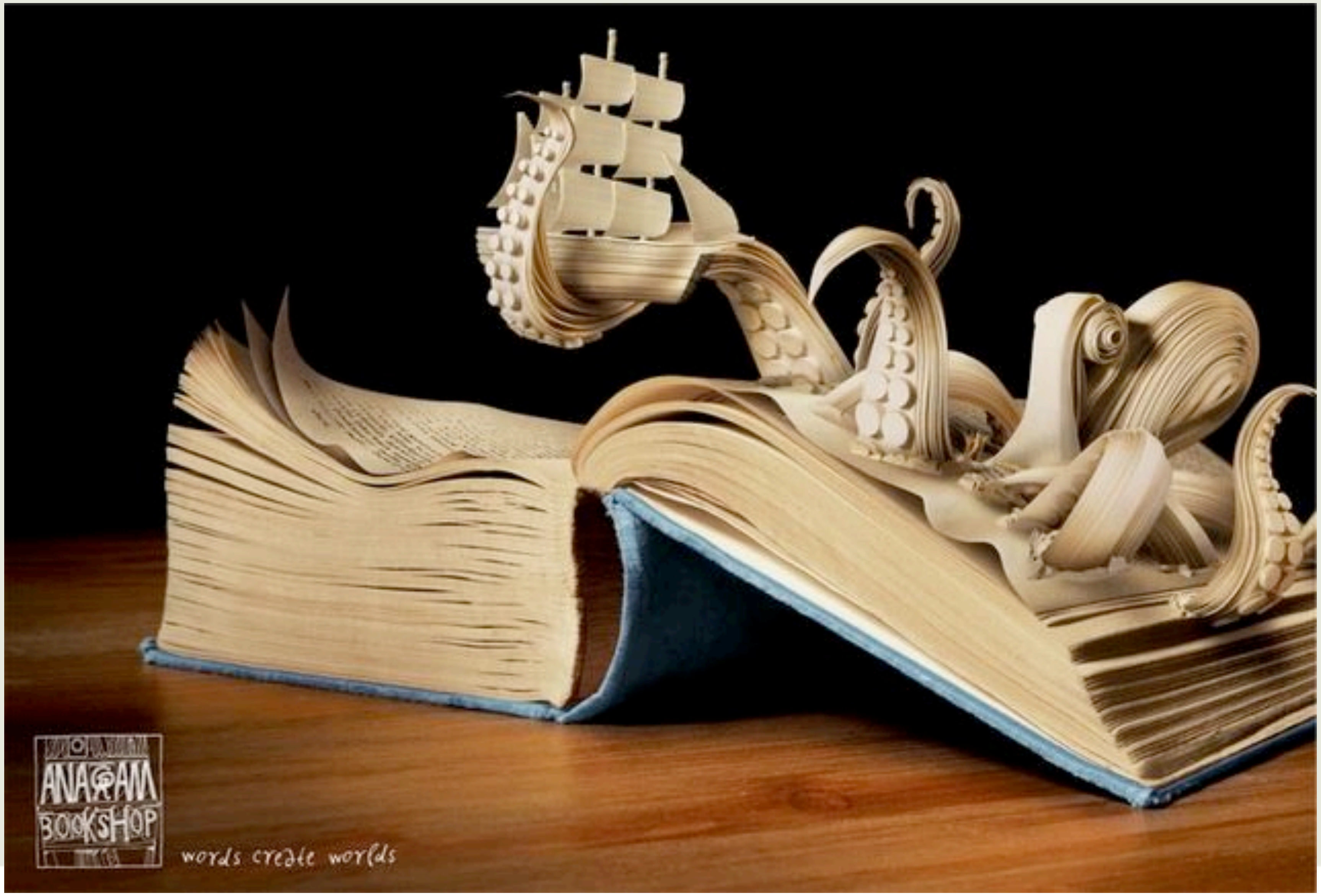

OmniTI / keeping users interested

Techniques / *Dynamic Content*

"We should forget about small efficiencies,
say about 97% of the time:
premature optimization is the root of all evil.
Yet we should not pass up our opportunities in that critical 3%.
A good programmer will not be lulled into complacency by such reasoning, he will be wise to look carefully at the critical code; but only after that code has been identified."

- Donald Knuth

"Knowing when optimization is premature defines the difference between the master engineer and the apprentice."

- me

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Techniques / *optimization*

- Optimization comes down to a simple concept: “don’t do work you don’t have to.”
- It can take the form of:
  - computational reuse
  - caching in a more general sense
  - and my personal favorite:
    - ... avoid the problem, and do no work at all.

Techniques / *optimization applied*

- Optimization in dynamic content simply means:
  - Don’t pay to generate the same content twice
  - Only generate content when things change
  - Break the system into components so that you can isolate the costs of things that change rapidly from those that change infrequently.
- There is a simple truth:
  - your content isn’t as dynamic as you think it is

Techniques / *optimization applied*

- Javascript, CSS and images are only referentially linked
- They should all be consolidated and optimized.
- They should be publicly cacheable and expire 10 years from now.
- RewriteRule (.*)\.([0-9]+)\.css $1.css
  - Means that /s/app.23412.css is just /s/app.css
  - different URL means new cached copy
  - any time the CSS is changed, just bump the number the application references from HTML.
  - Same applies for Javascript.
- Images... you should just deploy a new one at a new URI.

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Techniques / *per user info*

- If you could have a distributed database that:
  - when a node fails, you can guarantee no one needs the info on it
  - it is always located near the user accessing it
  - it can easily grow as your user base grows
- Introducing CookieDB:
  - it's been here all along
  - it's up in your browser
  - use it

Techniques / *data caching*

- Asking hard questions of database can be “expensive”
- You have two options:
    - cache the results
        - best when you can’t afford to be accurate
    - materialize a view on the changes
        - best when you need to be accurate

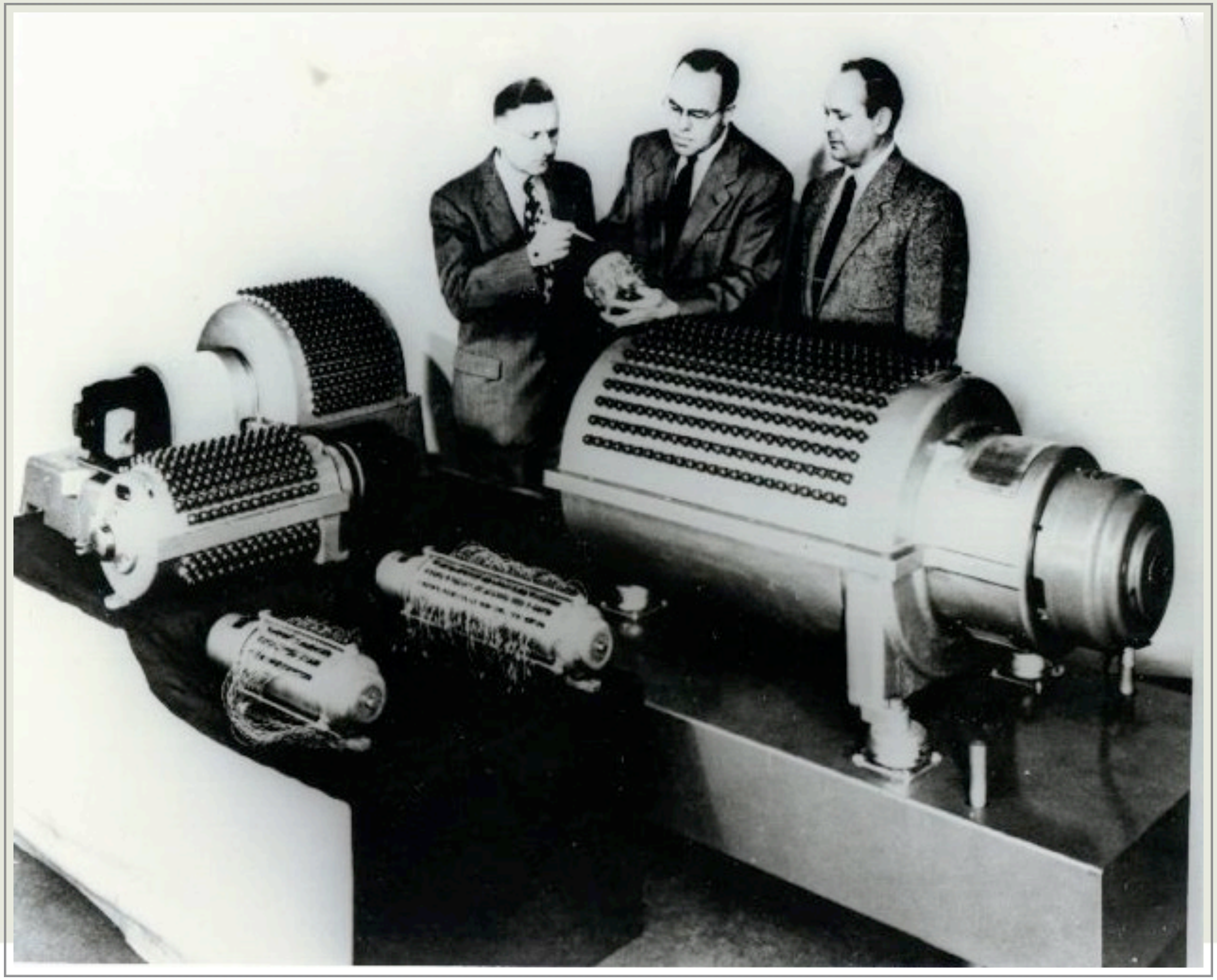
Techniques / *choosing technologies*

- Understand how you will be writing data into the system.
- Understand how you will be retrieving data from the system.
- WAIT… don't stop.
- Understand how everyone **else** in your organization will be retrieving data from the system.
- Research technologies and attempt find a good fit for your requirements: data access patterns, consistency, availability, recoverability, performance, stability
- This is not as easy as it sounds. It requires true technology agnosticism.

Rule / *K.I.S.S.*

#4 never solve a problem that you can otherwise avoid

#5 do not repeat work



OmniTI / remembering something useful

Techniques / *Databases*

- Rule 1: shard your database
- Rule 2: shoot yourself

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Databases / *second try*

- Horizontally scaling your databases via sharding/federating requires that you make concessions that should make you cry.
- shard (n.)
  a piece of broken ceramic, metal, glass, or rock typically having sharp edges.
- sharding (v.)
  dunno... but you will likely wound yourself and you get to keep all the pieces.
- But seriously...
  - databases (other than MySQL) scale vertically to a greater degree than many people admit.
  - if you must fragment your data, you will throw away relational constraints. this should make you cry. cry. cry hard. cry some more. then move on and shard your database.

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Databases / *vertical scaling*

- Many times relational constraints are not needed on data.
- If this is the case, a traditional ***relational*** database is unnecessary.
- There are cool technologies out there to do this:
  - "files"
  - noSQL
  - cookies
- Non-ACID databases can be easier to scale
- Vertical scaling is achieved via two mechanisms:
  - doing only what is absolutely necessary in the database
  - running a good database that can scale well vertically

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Databases / *horizontal scaling*

- Okay... so you really need to scale horizontally.
- understand the questions you intend to ask.
- make sure that you partition in a fashion that doesn't require more than a single shard to answer OLTP-style questions.
- If that is not possible, consider data duplication.

Databases / *an example*

- private messages all stored on the server side
  - individuals sends messages to their friends
  - an individual should see all messages sent to them
- Easy! partition by recipient.
  - either by hash
  - range partitions
  - whatever

Databases / *an example complicated*

- now users must be able to review all sent messages.
- Crap!
  - our recipient-based partitioning causes us to map the request across all shards to answer messages by sender.
- In this case:
  - store messages twice... once by recipient and once by sender
  - twice the storage, but queries only hit a single node now

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Databases / *Stepping outside of ACID*

- There are some alternatives to traditional RDBMS systems.
- Key-Value stores and document databases offer interesting alternatives.
- Without an imposed relational model federating/sharding is much easier to bake in.
- By relaxing consistency requirements, one can increase availability by adopting a paradigm of eventual consistency.
  - MongoDB
  - Cassandra
  - Voldemort
  - Redis
  - Riak

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Databases / *noSQL*

- noSQL systems aren't a cure-all data storage paradigm.
- A lot of data has relationships that are important.
- Referential integrity is quite important in many situations.
- A lot of datasets do not need to scale past a single instance.
- "Vertical scaling is not a strategy" is a faulty argument.
- Not every component of the architecture needs to scale past the limits of vertical scaling.
- If you can segregate your components, you can adhere to a right tool for the job paradigm. Use SQL where it is the best tool for the job and use distributed key-value stores and document databases in situations where they shine.

Databases / *when*

- break the problems down into small pieces and decouple them
- determine how large the problem is and can grow
- fit the solution to the problem
  - avoid: “shiny is good”
  - avoid: “over engineering”
  - embrace: “K.I.S.S.”
  - embrace: “good is good”

Databases / *reality or "unpopular opinion"*

- noSQL is the solution to today's Web 2.0 problems: not really
- traditional RDBMS patterns will take you to finish line: nope
- I can just replace my DBMS with a key-value store: not exactly
  - you must map your RPO and RTO and ACID requirements
  - good luck (again: break down the problems)

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Databases / *noSQL realities*

- noSQL systems are built to handle system failures.
- noSQL system performance numbers and stability reviews are never derived during failure conditions.
- noSQL systems tend to behave very badly during failure scenarios, because their operators assumed unaltered operations
- Think about the performance degradation of doing a filesystem backup of a traditional RDBMS during peak usage
  - (sadly many do not do or think about this)
- in failure scenario of noSQL, similar such taxes exist, but:
  - people tend to operate them under heavy load with no headroom
  - the headroom for node recovery and degraded operation are quire large.

#6 appropriateness is both comprehensive and objective

OmniTI / actually delivering

Techniques / *Networking*

- The network is part of the architecture.
- So often forgotten by the database engineers and the application coders and the front-end developers and the designers.
- Packets per second, firewall states, load balancing algorithms, etc.
- Many apps today are so poorly designed that network issues never become scalability concerns... others can really toss the bits.
- This is for the application architectures that have high traffic rates.

Networking / *basics*

- Scalability on the network side is all about:
    - understanding the bottleneck
    - avoiding the single point of failure
    - spreading out the load.

Networking / *going past gigE*

- A single machine can push 1 GigE.
- Actually more than a GigE isn't too hard.
- But how to push 10 or 20?
- Buy a really expensive load balancer?
- ... there are other ways to manage this a bit cheaper.

Networking / *going past gigE*

- use routing.
- routing supports extremely naive load balancing.
- run a routing protocol on the front-end ‘uber-caches’
- have the upstream use hashed routes
- the user-caches announce the same IP.
- this adds fault-tolerance and distributes network load.
- and it is pretty much free (no new equipment in the path).
- *note: your ‘uber-caches’ may be load balancers themselves*.

Networking / *isolation*

- for those that run multiple services on the same network.
- one service bursting on a.b.c.67 might saturate firewall and/or load-balancer capacity and degrade services other services behind the same infrastructure.
- again... routing to the rescue.
- set up a separate set of firewalls/load-balancers that reside in a "surge" net. Those firewalls only need to announce the /32 of the surging service to assume control of the traffic.

  note: you need some trickery to make sure return traffic is symmetric
- This is the same technique used to protect against DDoS attacks.

#7 solutions should be as close to the customer as possible

OmniTI / controlling experience by removing ‘the suck’

Techniques / *Service Decoupling*

- One of the most fundamental techniques for building scalable systems
- Asynchrony...
  - Why do now what you can postpone until later?
    - This mantra often doesn't break a user's experience.
- Break down the user transaction into parts.
- Isolate those that could occur asynchronously.
- Queue the information needed to complete the task.
- Process the queues "behind the scenes."

Techniques / *Service Decoupling*

- Asynchrony… that’s not really what it means.
  - It isn’t exactly about postponing work (though that can happen).
  - It is about service isolation.
- By breaking the system in to small parts we gain:
  - problem simplification,
  - fault isolation,
  - decoupling of approach, strategy and tactics,
  - simplified design,
  - models for performance that are more likely to be accurate, and
  - simplified overall capacity planning.

Decoupling / *concept*

- If I don't want to do something now...
- I must tell someone to do it later.

- This is "messaging"

- There are a lot of solutions:
  - JMS (Java message service)
  - Spread (extended virtual synchrony messaging bus)
  - AMQP (advanced message queueing protocol)
  - ZeroMQ ("Fast" messaging)

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Decoupling / *awareness*

- (most) asynchronous (and, even more so, distributed) systems are:
  - complex
  - non-sequential
  - self-inconsistent
  - under-engineered
  - under-instrumented
  - unnecessary
  - scale very very well

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Decoupling / *control*

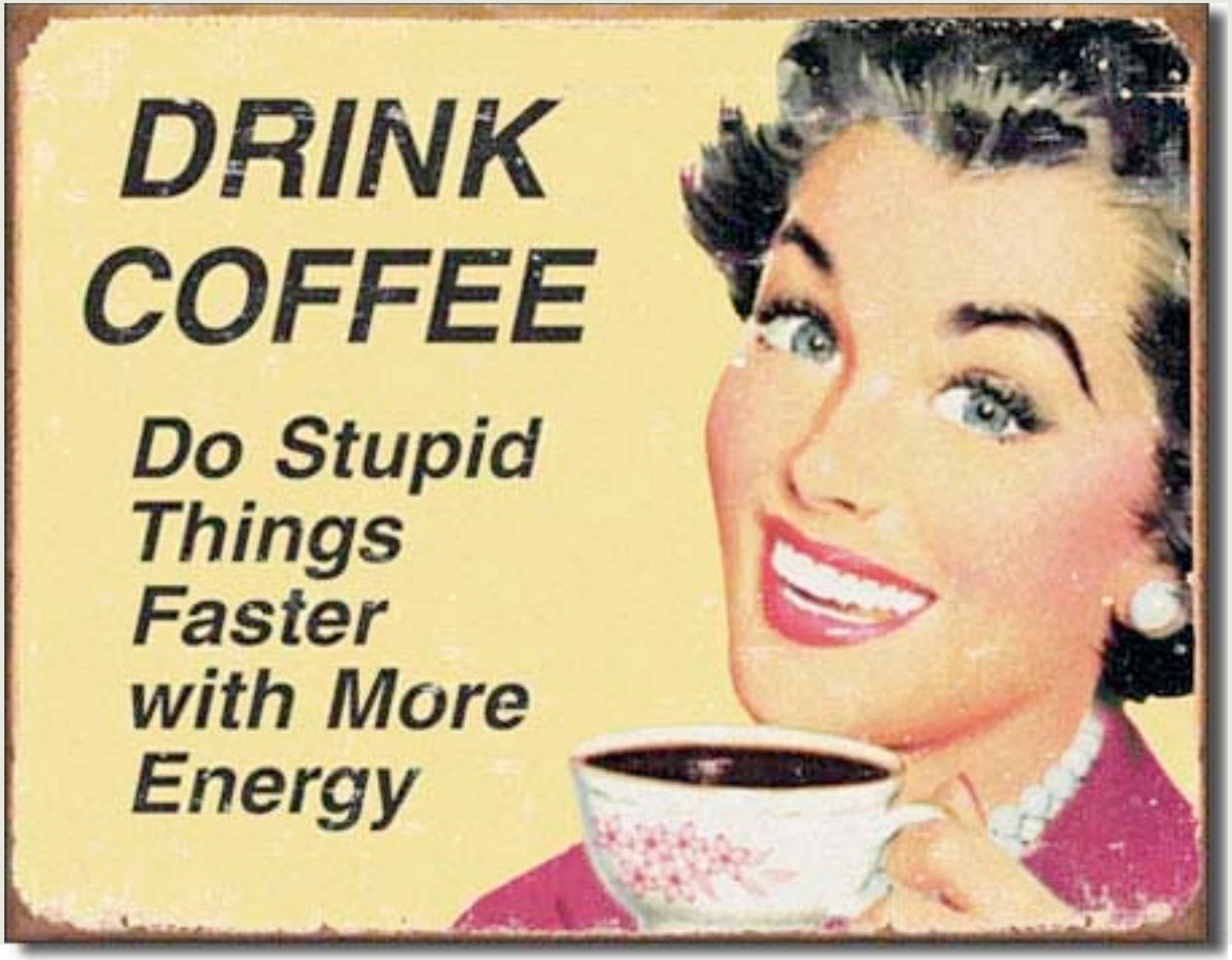
"Moderation in all things, including moderation."

- Titus Petronius
AD 27-66

Rule / *avoid Satan*

#8 complexity is the devil

#9 deal with the devil only when necessary



most scalability problems are due to idiocy

WTF / *don't be an idiot*

- most acute scalability disasters are due to idiots
- don't be an idiot
- scaling is hard
- performance is easier
- extremely high-performance systems tend to be easier to scale
  - because they don't have to

SCALE

as much.

WTF / *sample 1*

- Hey! let's send a marketing campaign to:

  http://example.com/landing/page

- ```
  GET /landing/page HTTP/1.0
  Host: example.com

  HTTP/1.0 302 FOUND
  Location: /landing/page/
  ```
  ```

WTF / *sample 2*

- I have 100k rows in my users table...
- I'm going to have 10MM...
- I should split it into 100 buckets,
  with 1MM per bucket so I can scale to 100MM.
- The fundamental problem is that I don't *understand* my problem.

- I know what my problems are with 100k users... or do I?
- There is some margin for error...
  you design for 10x...
  as you actualize 10x growth you will (painfully) understand that margin.
- Designing for 100x let alone 1000x
  requires a ***profound*** understanding of their problem.
- Very few have that.

WTF / *sample 3*

- I plan to have a traffic spike from (link on MSN.com)
- I expect 3000 new visitors per second.
- My page http://example.com/coolstuff is 14k
  2 css files each at 4k
  1 js file at 23k
  17 images each at ~16k
  (everything's compressed)
- /coolstuff is CPU bound (for the sake of this argument)
  I've tuned to 8ms services times...
  8 core machines at 90% means 7200ms of CPU time/second...
  900 req/second per machine...
  3000 v/s / 900 r/s/machine / 70% goal at peak rounded up is...
  5 machines (6 allowing a failure)
- the other files I can serve faster... say 30k requests/second from my Varnish instances... 3000 v/s * 20 assets / 30k r/s/varnish / 70% is...
  3 machines (4 allowing a failure).

WTF / *sample 3, the forgotten part*

- 14k + 2 * 4k + 1 * 23k + 17 * 16k = 21 requests with 317k response
- (317k is 2596864 bits/visit) * 3000 visits/second = 7790592000 b/s
- just under 8 gigabits per second.
- even naively, this is 500 packets per visitor * 3000 visitors/second
- 1.5MM packets/second.

- This is no paltry task...
- 20 assets/visit are static content, we know how to solve that: CDN.
- the rest? ~350 megabits per second and ~75k packets/second
- perfectly manageable, right?
- a bad landing link that 302's adds ~30k packets/second... Crap.

#10 don't be a fucking idiot

Rule / *competency required*

#10 idiocy is bad

(and contagious)

Thank You

- Thank you OmniTI & Circonus
- We're hiring
- Surge 2012 - http://omniti.com/surge
- Thank you!