Monkeys in Lab Coats

Automating Failure Testing Research at

The whole is greater than the sum of its parts.

- Aristotle
[Metaphysics]

The Professor

The Practitioner

Peter Alvaro

Kolton Andrus

Ex-Berkeley, Ex-Industry

Assistant Prof @ Santa Cruz

Misses the calm of PhD life

Likes prototyping stuff

Ex-Netflix, Ex-Amazon

‘Chaos’ Engineer

Misses his actual pager

Likes breaking stuff

Measures of Success

Academic

H-Index

Grant warchest

Department ranking

Industry

Availability (i.e. 99.99% uptime)

Number of Incidents

Reduce Operational Burden

An Unlikely Team?


NETFLIX
Fail U re as
238.029
+2
+3
+4
+5
+6
92
2-8-18-32-21-9-2
a Se rvice
78.96
-2
+1
+2
+4
+6
34
2-8-18-6

Works Great!

but ... it’s manual

Surely there is a better way ...


Chrome File Edit View History Bookmarks People Window Help
https://www.youtube.com/watch?v=ggCffvKEJmQ
YouTube
Lineage-driven fault injection
Goal: top-down testing that
• finds all of the fault-tolerance bugs, or
• certifies that none exist
RICON
RICON 2014: Keynote 2 Day 2: Peter Alvaro - Outwards from the Middle of the Maze
Basho Technologies
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Peter Alvaro, PhD candidate at UC Berkeley
Outwards from the middle of the maze
Wednesday, October 29th
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amazon

Free lunch?

The End?

(Academia + Industry)

Let’s build it

“Can we, pretty please?”

Freedom and Responsibility

NETFLIX Core Value

Responsibility

Academic

Industry

Prove that it works

Show that it scales

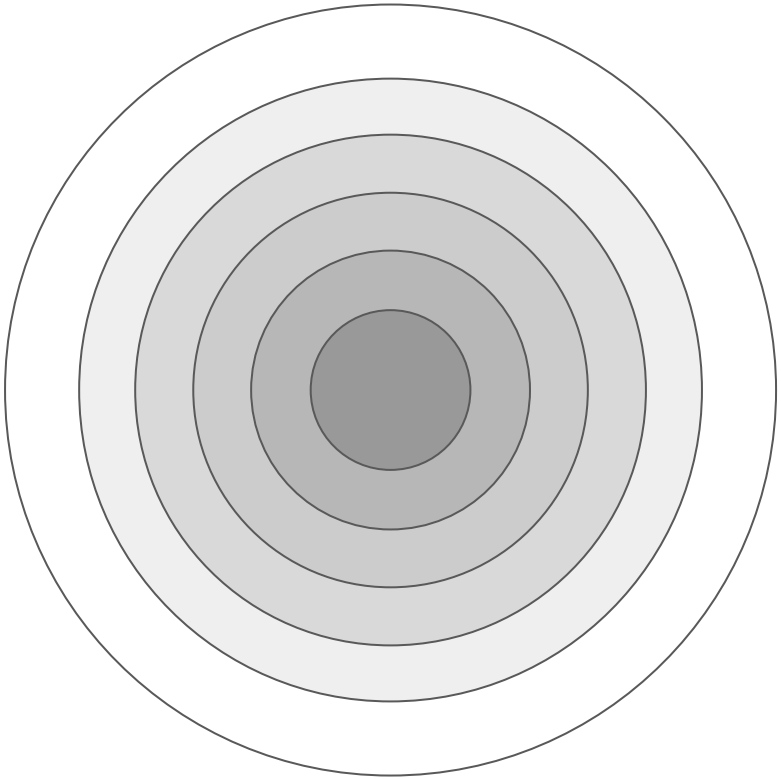
Find real bugs

The Big Idea

Lineage Driven Fault Injection

What could *possibly* go wrong?

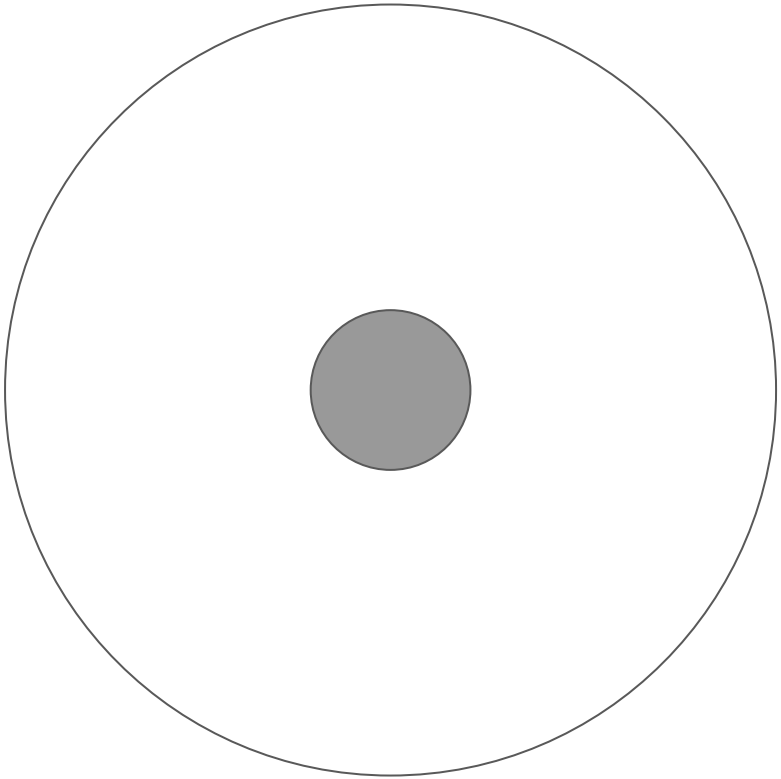
Consider computation involving 100 services



Search Space: 2^{100} executions

“Depth” of bugs

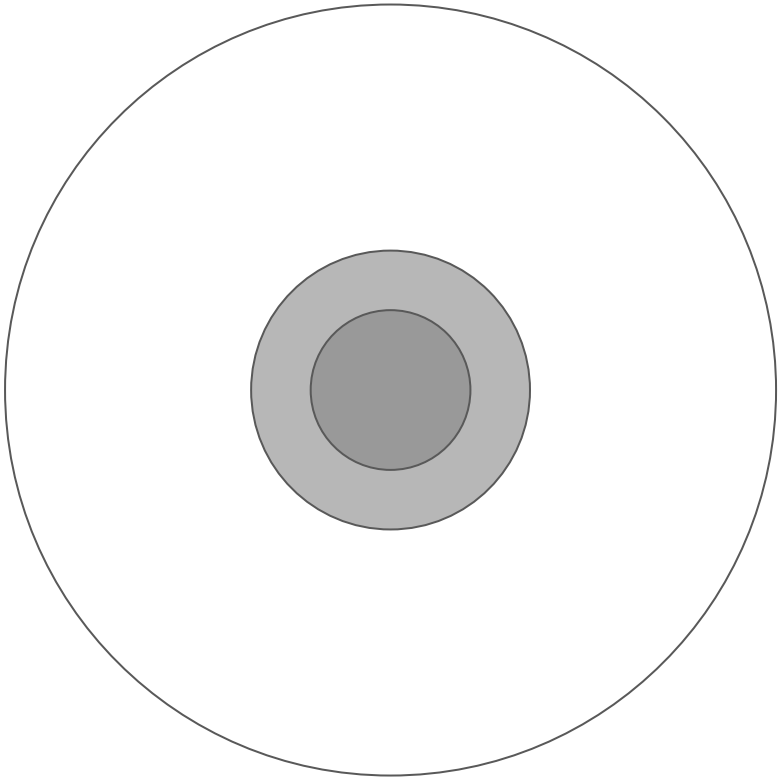
Single Faults



Search Space:
100 executions

“Depth” of bugs

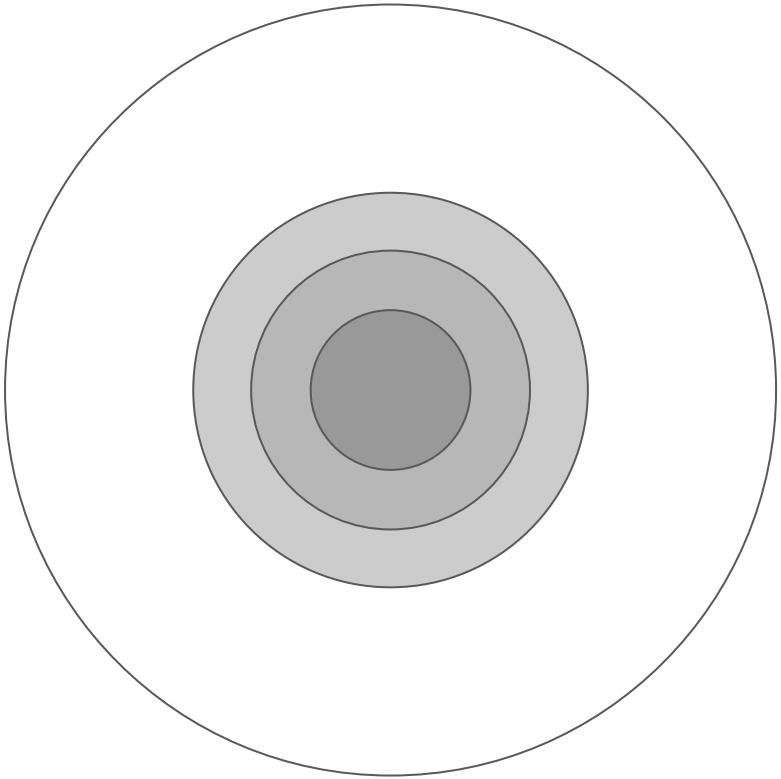
Combination of 4 faults



Search Space:
3M executions

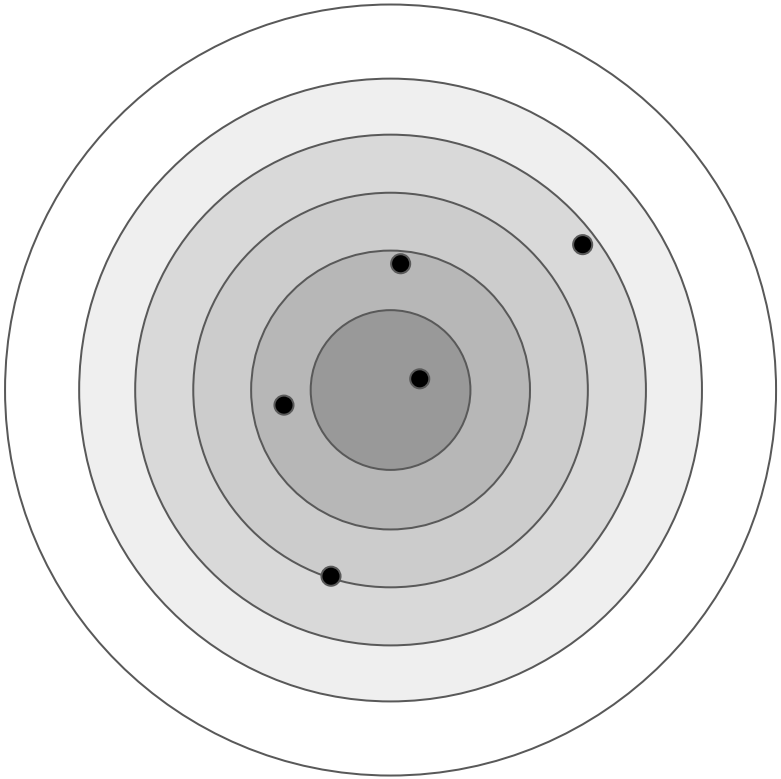
“Depth” of bugs

Combination of 7 faults



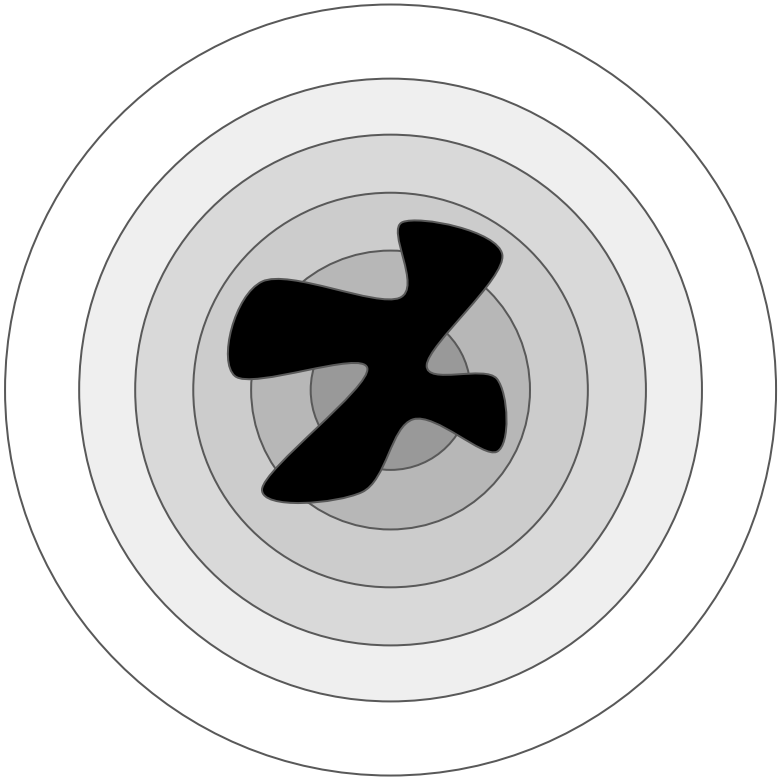
Search Space:
16B executions

Random Search



Search Space:
2^{100} executions

Engineer-guided Search



Search Space:
???

Fault-tolerance “is just” redundancy

Lineage-driven Fault Injection

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ABSTRACT

Failure is always an option; in large-scale data management systems, it is practically a certainty. Fault-tolerant protocols and components are notoriously difficult to implement and debug. Worse still, choosing existing fault-tolerance mechanisms and integrating them correctly into complex systems remains an art form, and programmers have few tools to assist them.

We propose a novel approach for discovering bugs in fault-tolerant data management systems: *lineage-driven fault injection*. A lineage-driven fault injector reasons *backwards* from correct system outcomes to determine whether failures in the execution could have prevented the outcome. We present MOLLY, a prototype of lineage-driven fault injection that exploits a novel combination of data lineage techniques from the database literature and state-of-the-art satisfiability testing. If fault-tolerance bugs exist for a particular configuration, MOLLY finds them rapidly, in many cases using an order of magnitude fewer executions than random fault injection. Otherwise, MOLLY certifies that the code is bug-free for that configuration.

enriching new system architectures with well-understood fault tolerance mechanisms and henceforth assuming that failures will not affect system outcomes. Unfortunately, fault-tolerance is a *global* property of entire systems, and guarantees about the behavior of individual components do not necessarily hold under composition. It is difficult to design and reason about the fault-tolerance of individual components, and often equally difficult to assemble a fault-tolerant system even when given fault-tolerant components, as witnessed by recent data management system failures [16, 57] and bugs [36, 49].

Top-down testing approaches—which perturb and observe the behavior of complex systems—are an attractive alternative to verification of individual components. Fault injection [1, 26, 36, 44, 59] is the dominant top-down approach in the software engineering and dependability communities. With minimal programmer investment, fault injection can quickly identify shallow bugs caused by a small number of independent faults. Unfortunately, fault injection is poorly suited to discovering rare counterexamples involving complex combinations of multiple instances and types of faults (e.g., a network partition followed by a crash failure). Ap-

How do we find the redundancy?

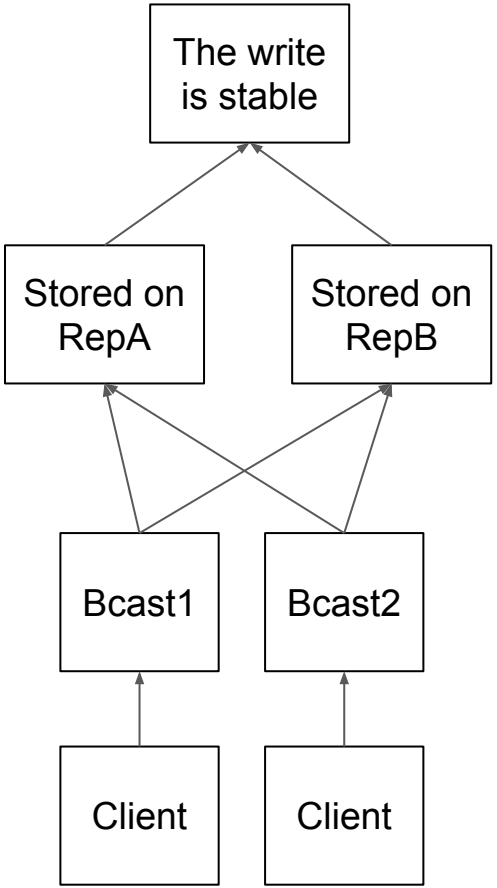
~~Could a bad ‘thing’ ever happen?~~

Why did a good ‘thing’ happen?

Lineage-driven fault injection

Why did a good thing happen?

Consider its *lineage*.



Lineage-driven fault injection

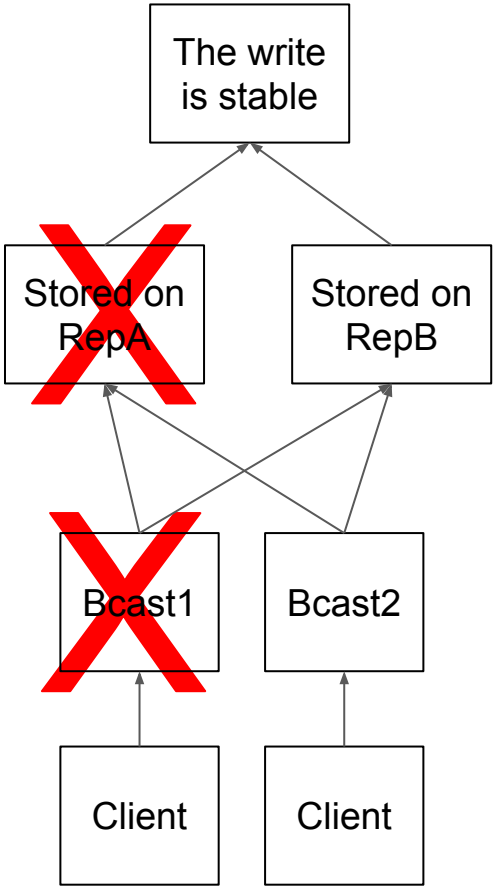
Why did a good thing happen?

Consider its *lineage*.

What could have gone wrong?

Faults are *cuts* in the lineage graph.

Is there a cut that breaks all supports?



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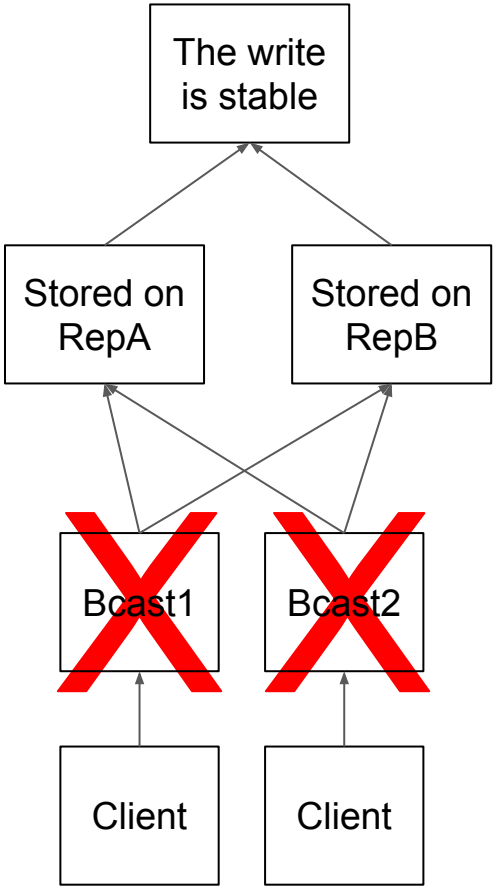
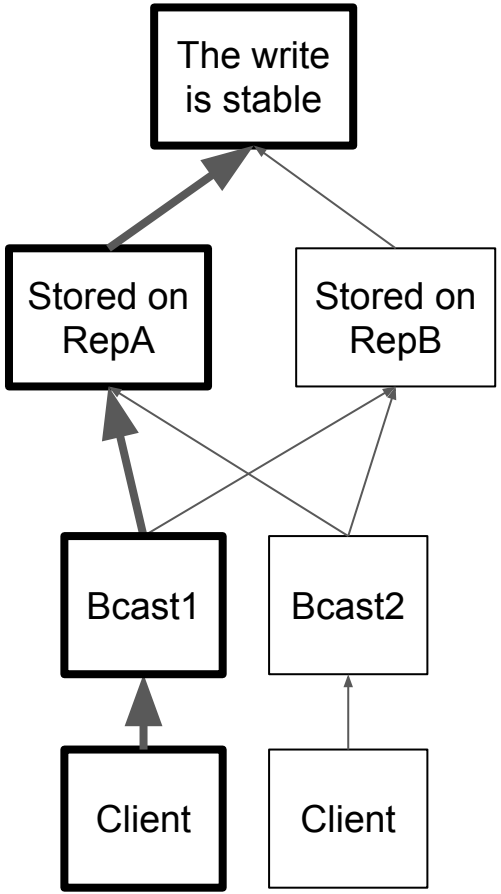


What would *have to* go wrong?

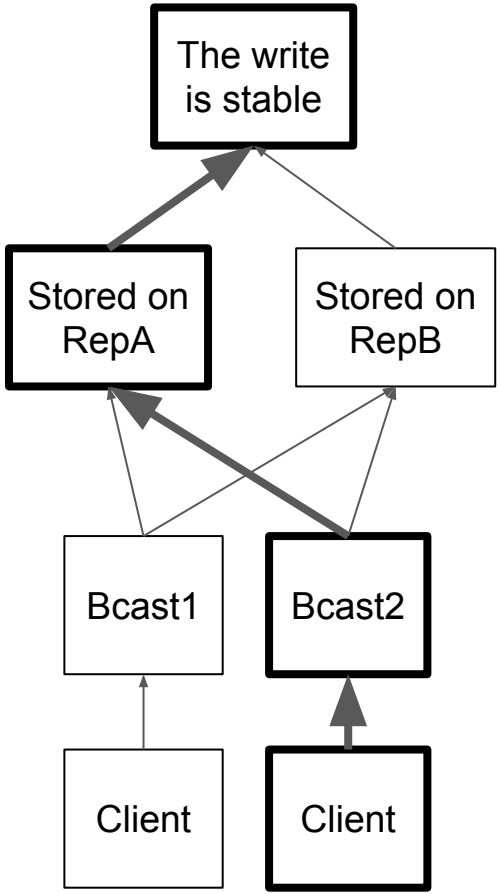
(RepA OR Bcast1)



What would *have to* go wrong?

(RepA OR Bcast1)

AND (RepA OR Bcast2)

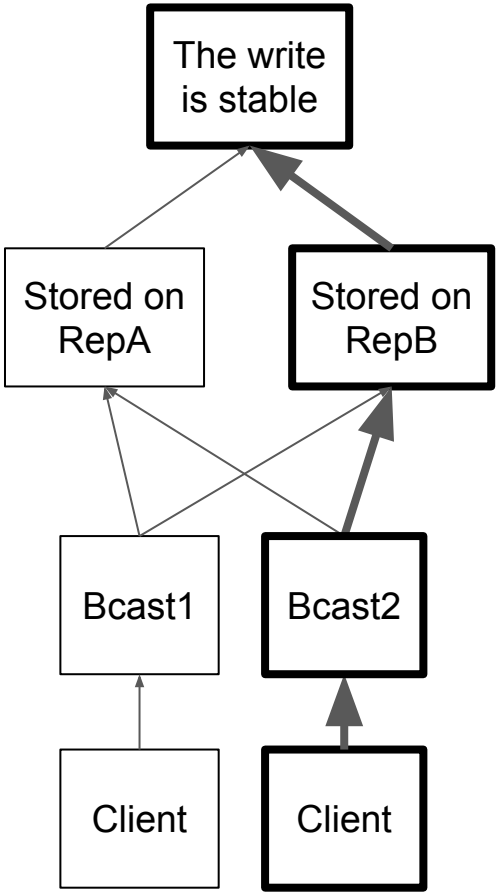


What would *have to* go wrong?

(RepA OR Bcast1)

AND (RepA OR Bcast2)

AND (RepB OR Bcast2)



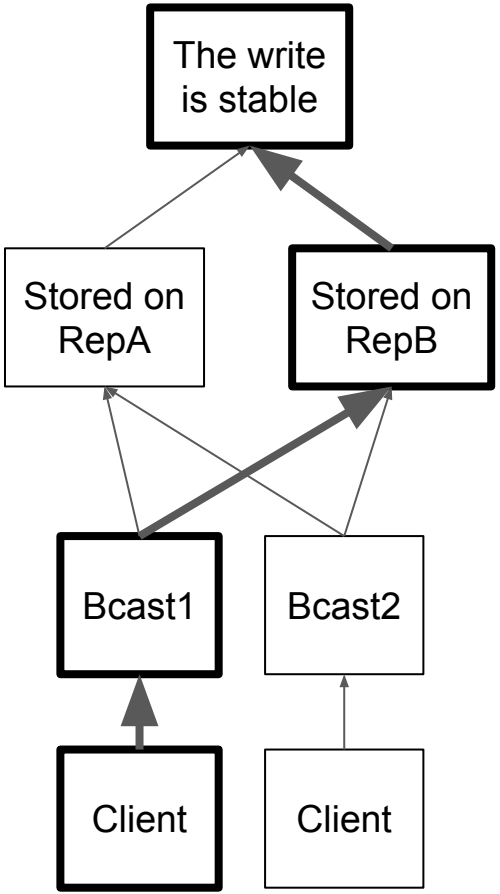
What would *have to* go wrong?

(RepA OR Bcast1)

AND (RepA OR Bcast2)

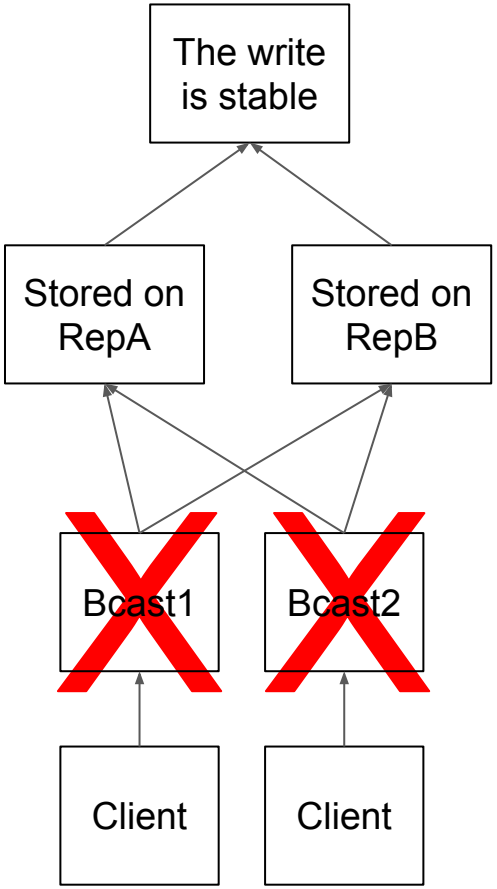
AND (RepB OR Bcast2)

AND (RepB OR Bcast1)



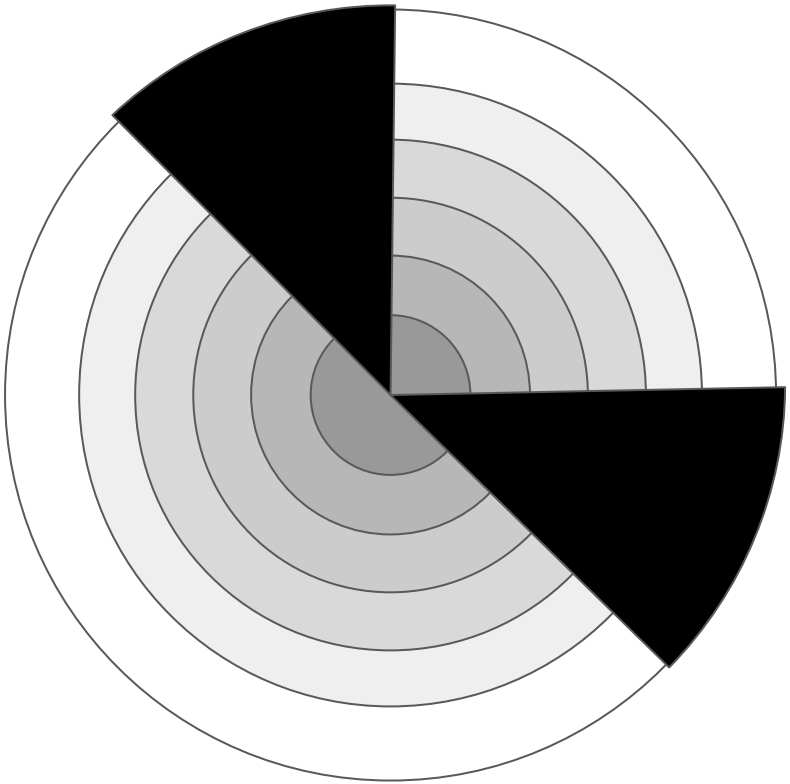
Lineage-driven fault injection

Hypothesis: {Bcast1, Bcast2}



Search Space Reduction

Each Experiment finds a bug, OR

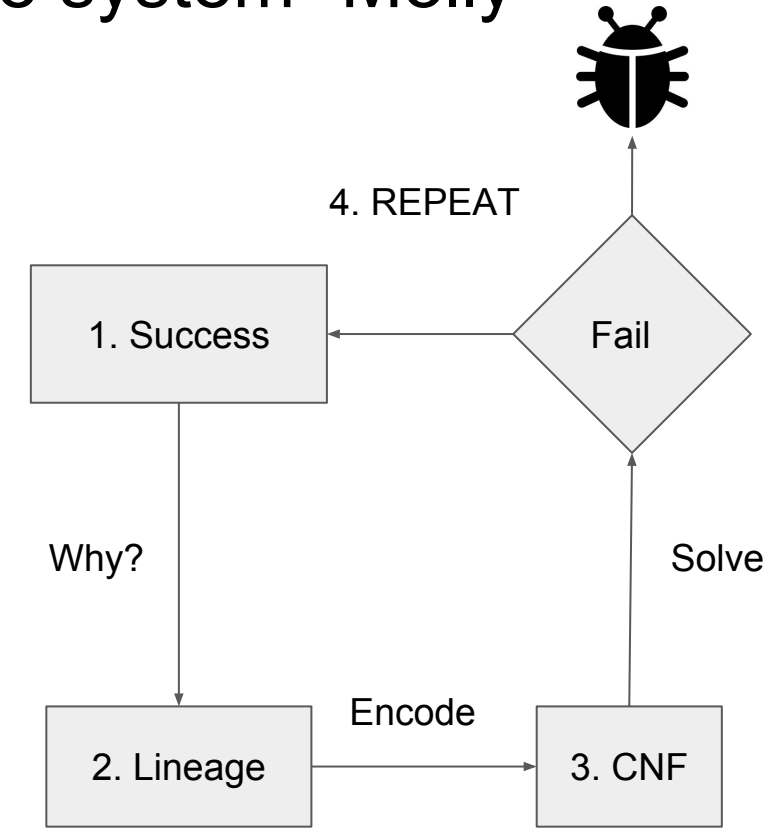


Reduces the Search space

The prototype system “Molly”

Recipe:

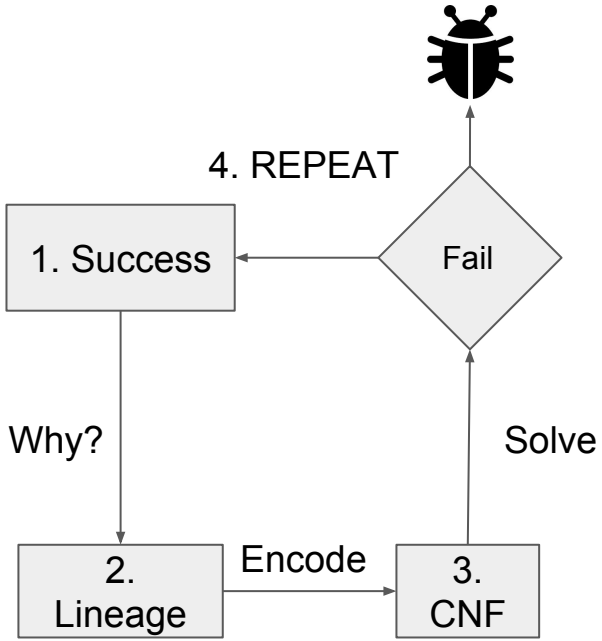
1. Start with a successful outcome. Work backwards.
2. Ask *why* it happened: Lineage
3. Convert lineage to a boolean formula and solve
4. Lather, rinse, repeat



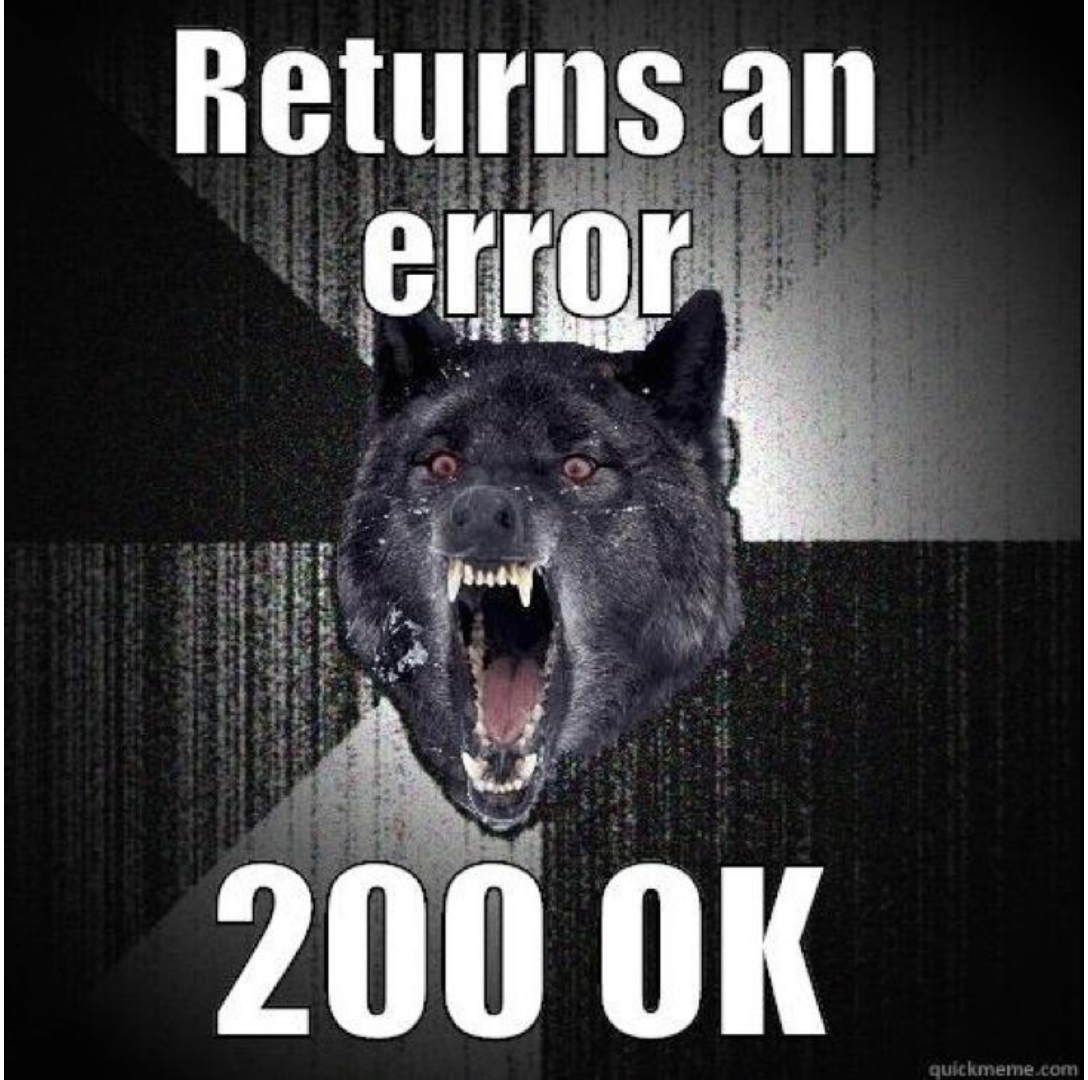
The Big Idea

Meets Production

1. Start with a successful outcome



What is success?


Returns an error
200 OK
quickmeme.com

“Start with the customer and work backwards”

amazon Leadership Principle

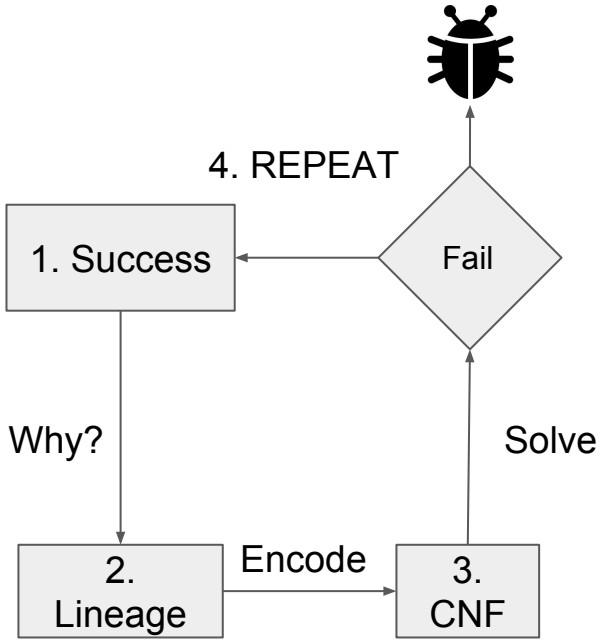

NETFLIX
XBOX 360
NETFLIX
UNBREAKABLE
KIMMY SCHMIDT
SAMSUNG
NETFLIX
MARCO
POLO


NETFLIX
Unable to connect to Netflix. Please try again or visit:
www.netflix.com/tvhelp
Try Again
Exit
ui-200
NETFLIX

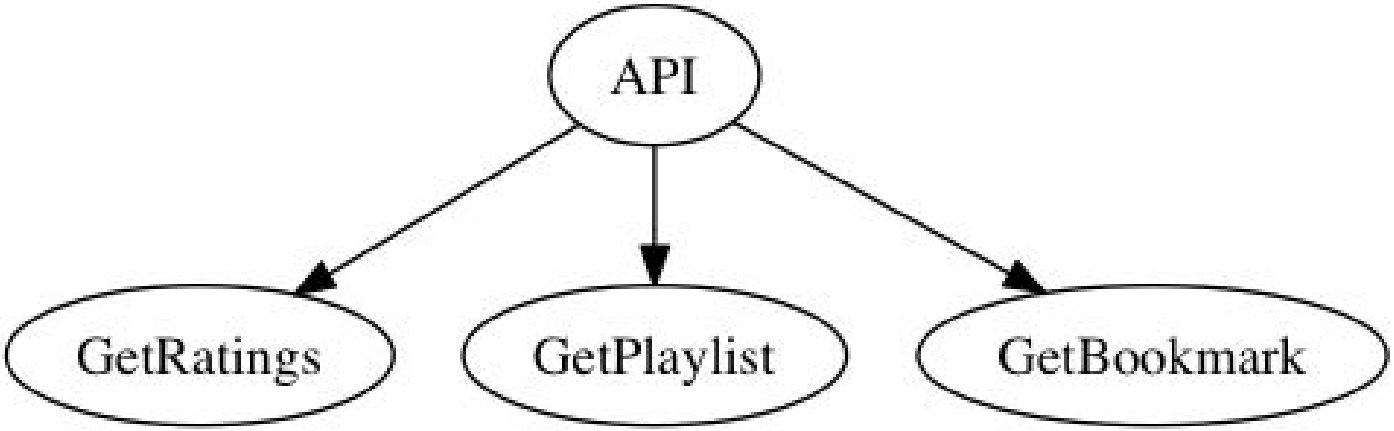
Lesson 1

Work backwards from what you know

2. Ask why it happened

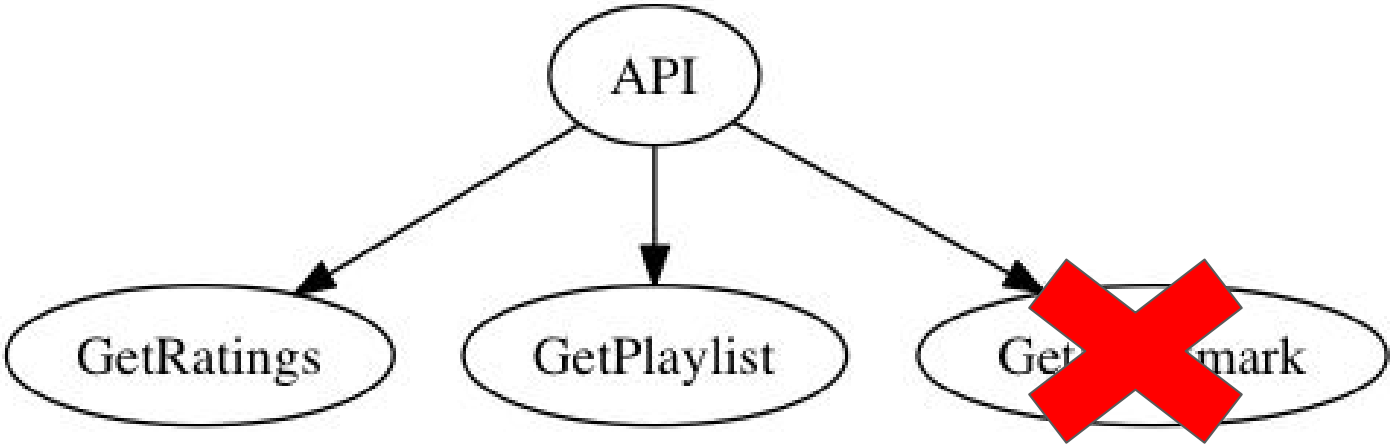


Request Tracing

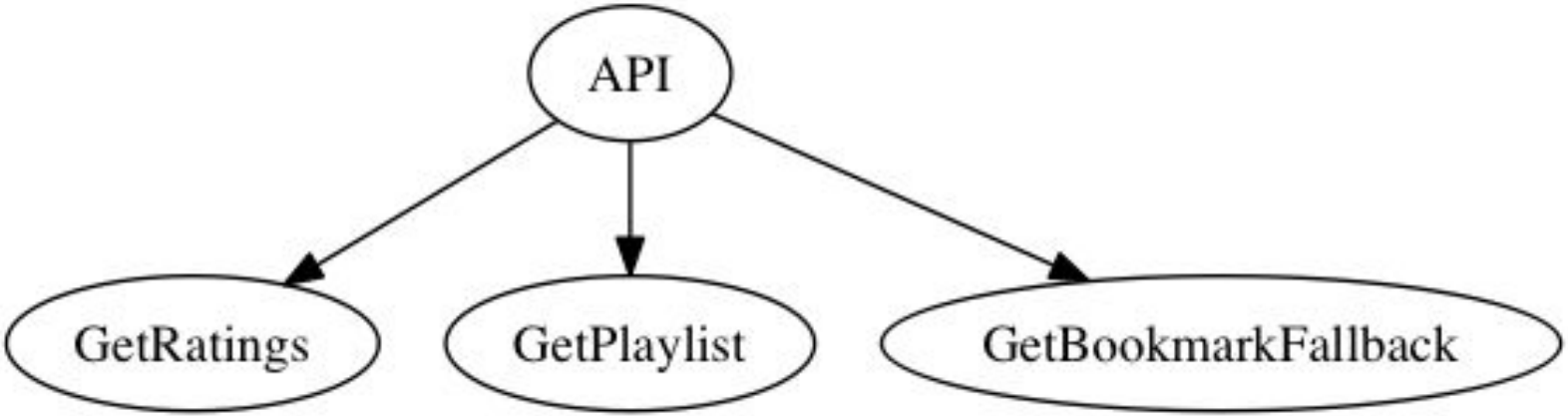



GAME
OVER

Request Tracing

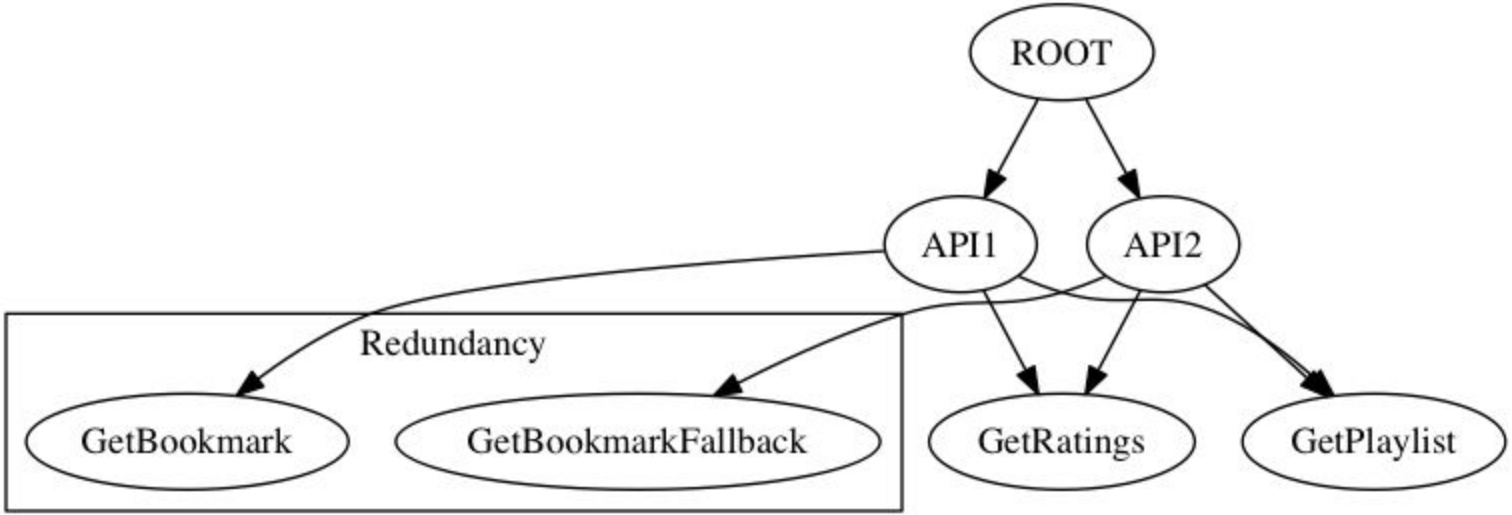


Alternate Execution



Evolution over time

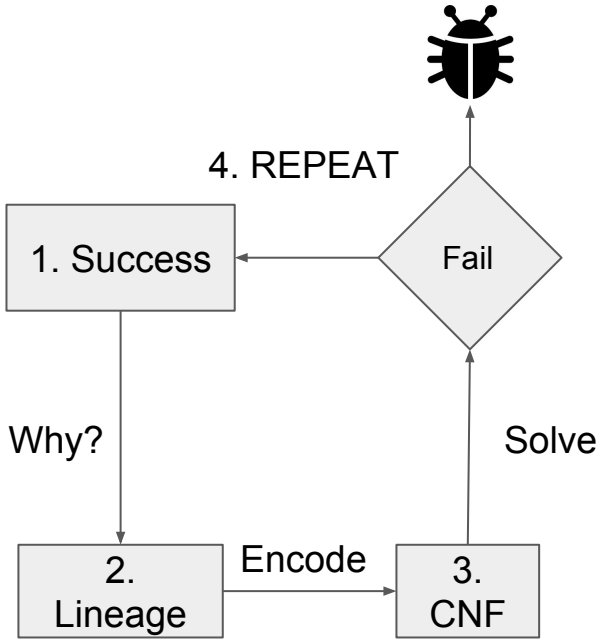
Redundancy through History



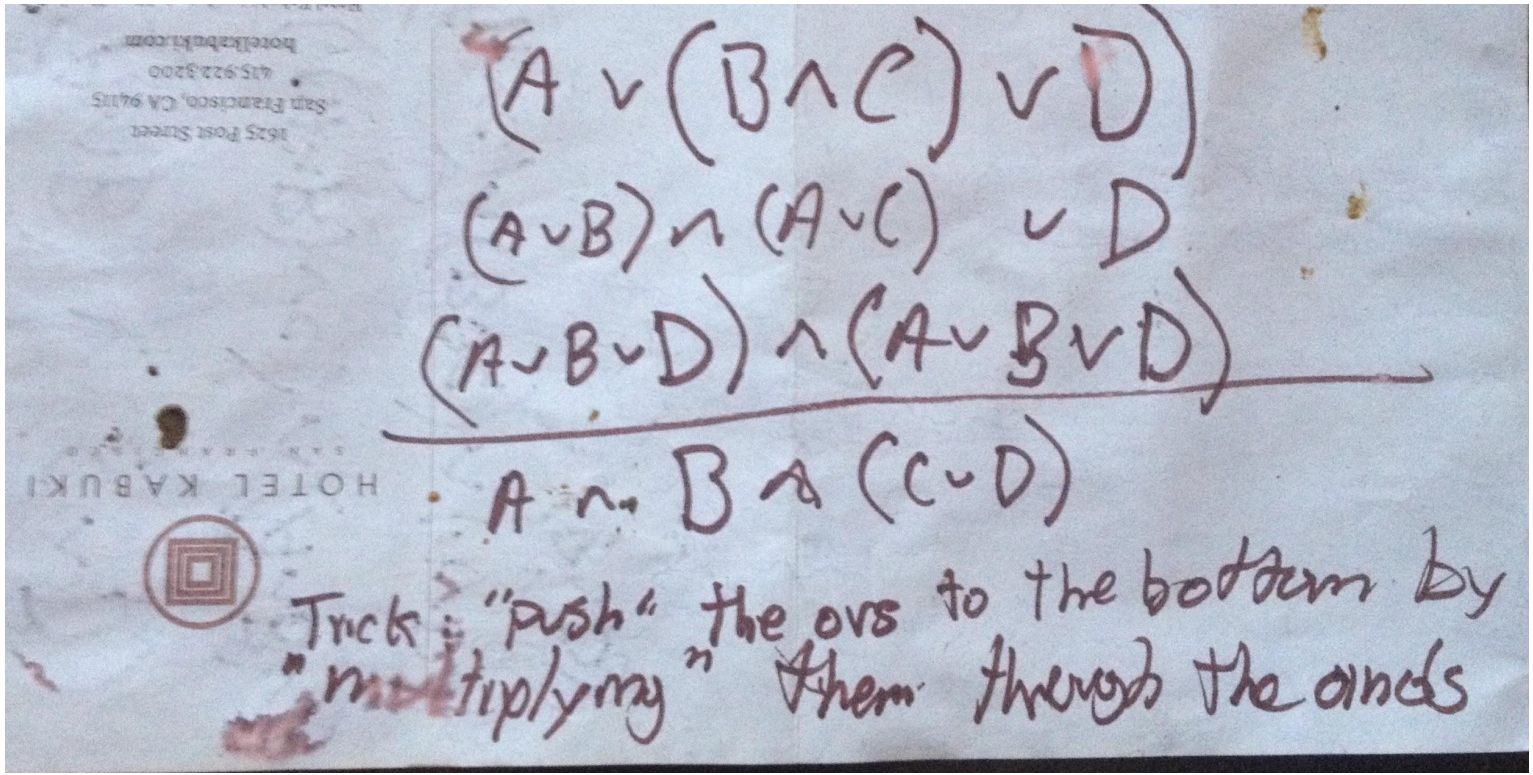
Lesson 2

Meet in the middle

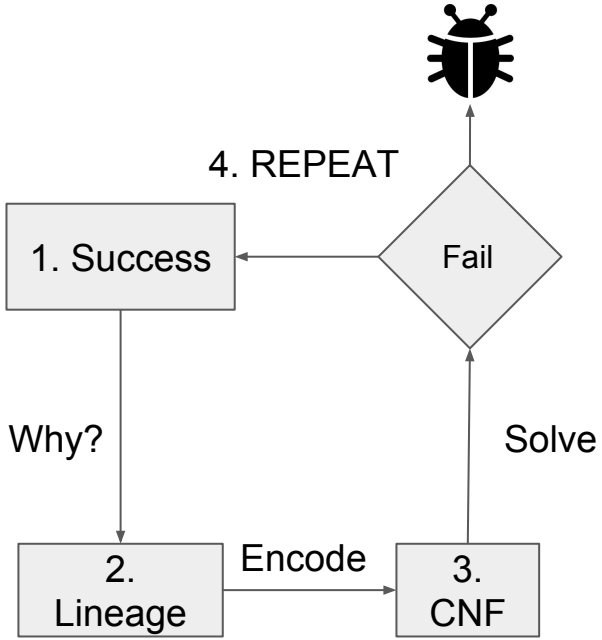
3. Solve



A “small” matter of code

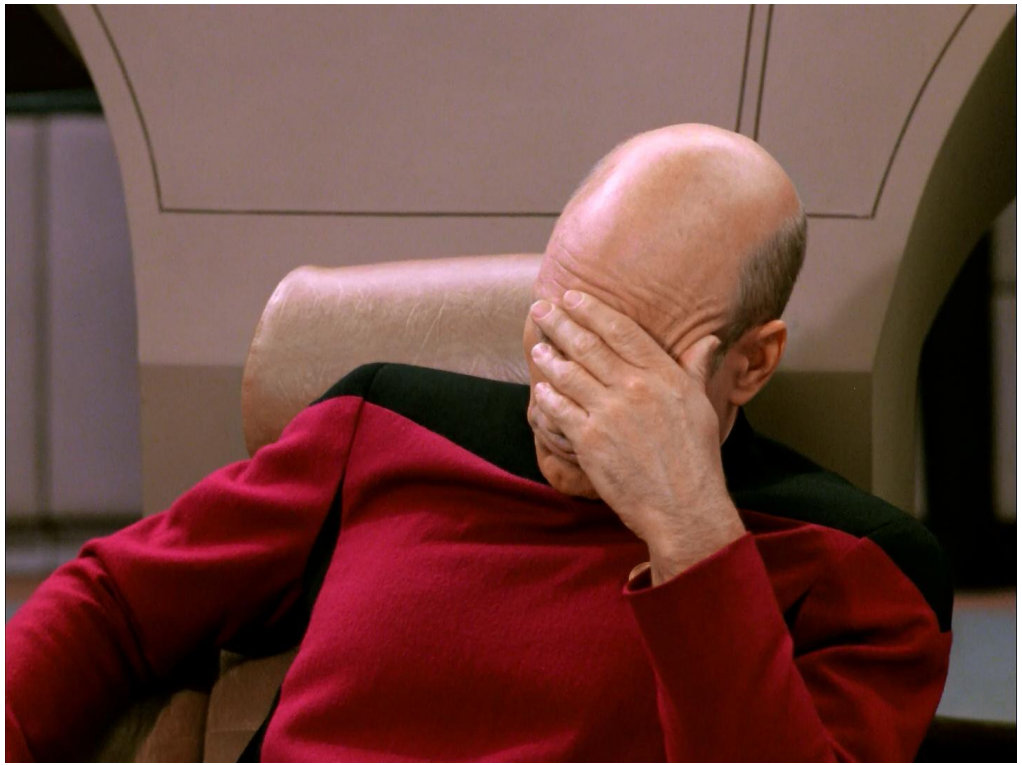


4. Lather, Rinse, Repeat



Turn the crank, right?

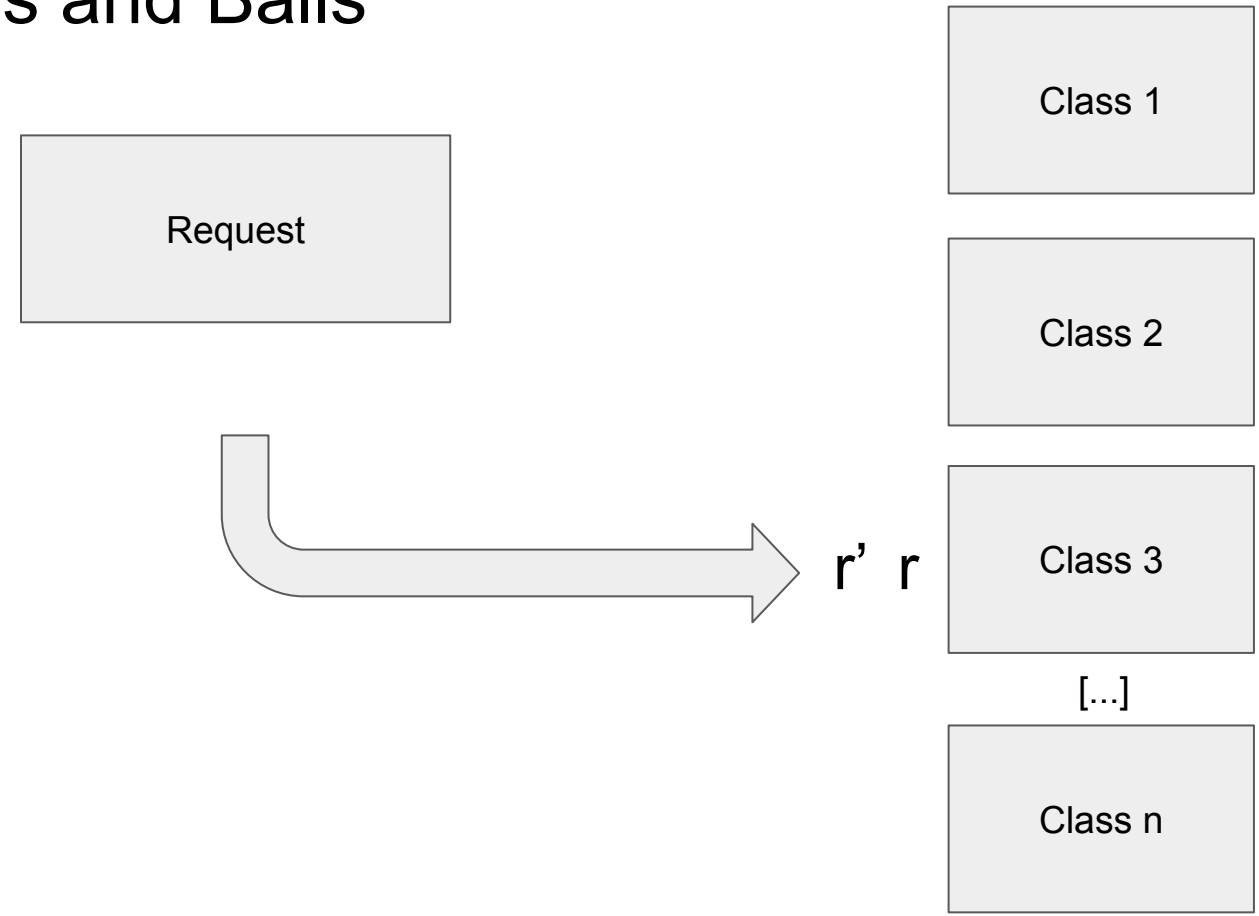
Idempotence



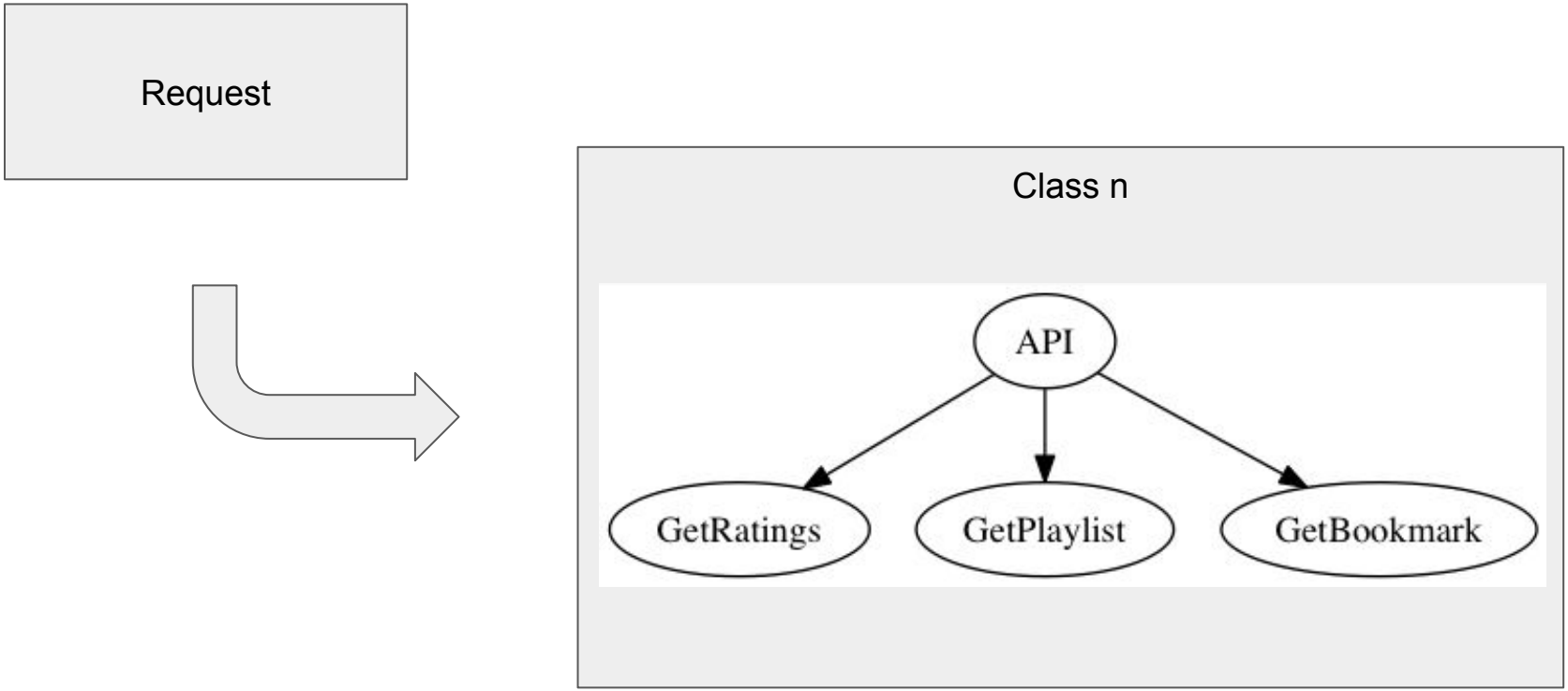

©NEILWADE.COM


GAME
OVER

Bins and Balls

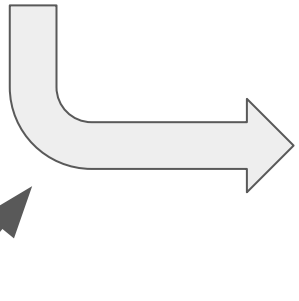


Predicting Request Graphs

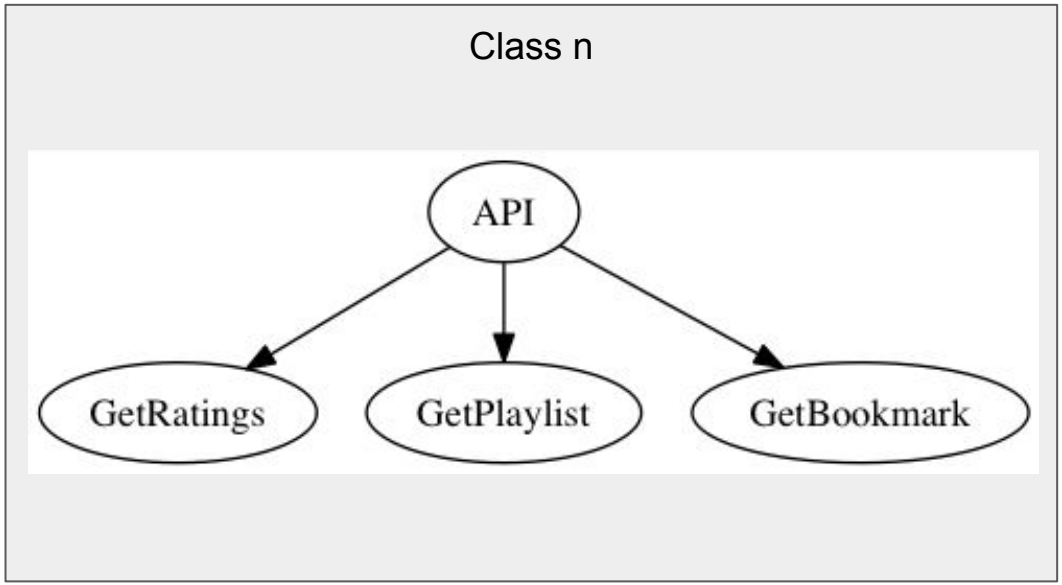


Predicting Request Graphs

Request

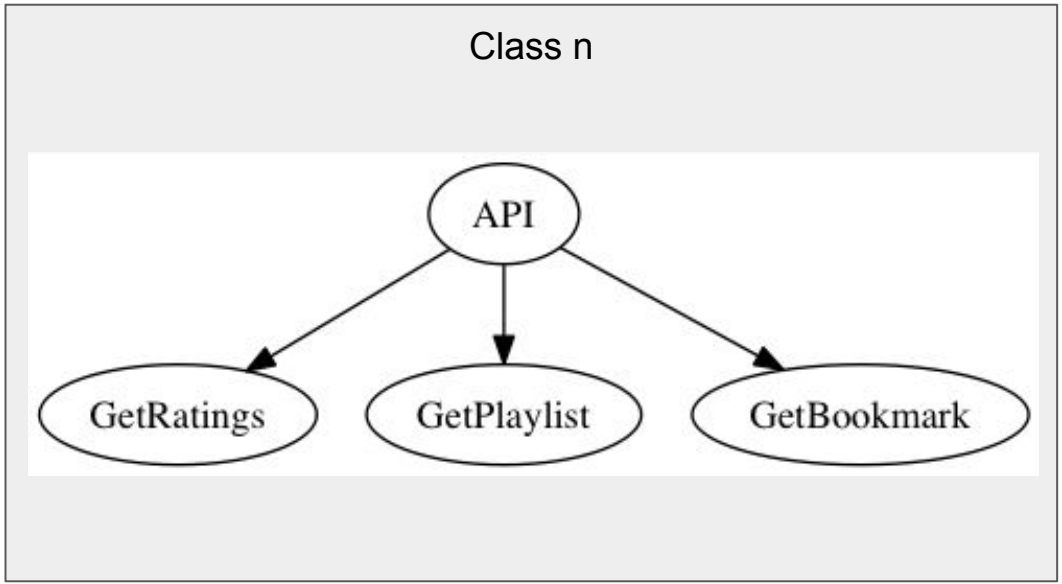


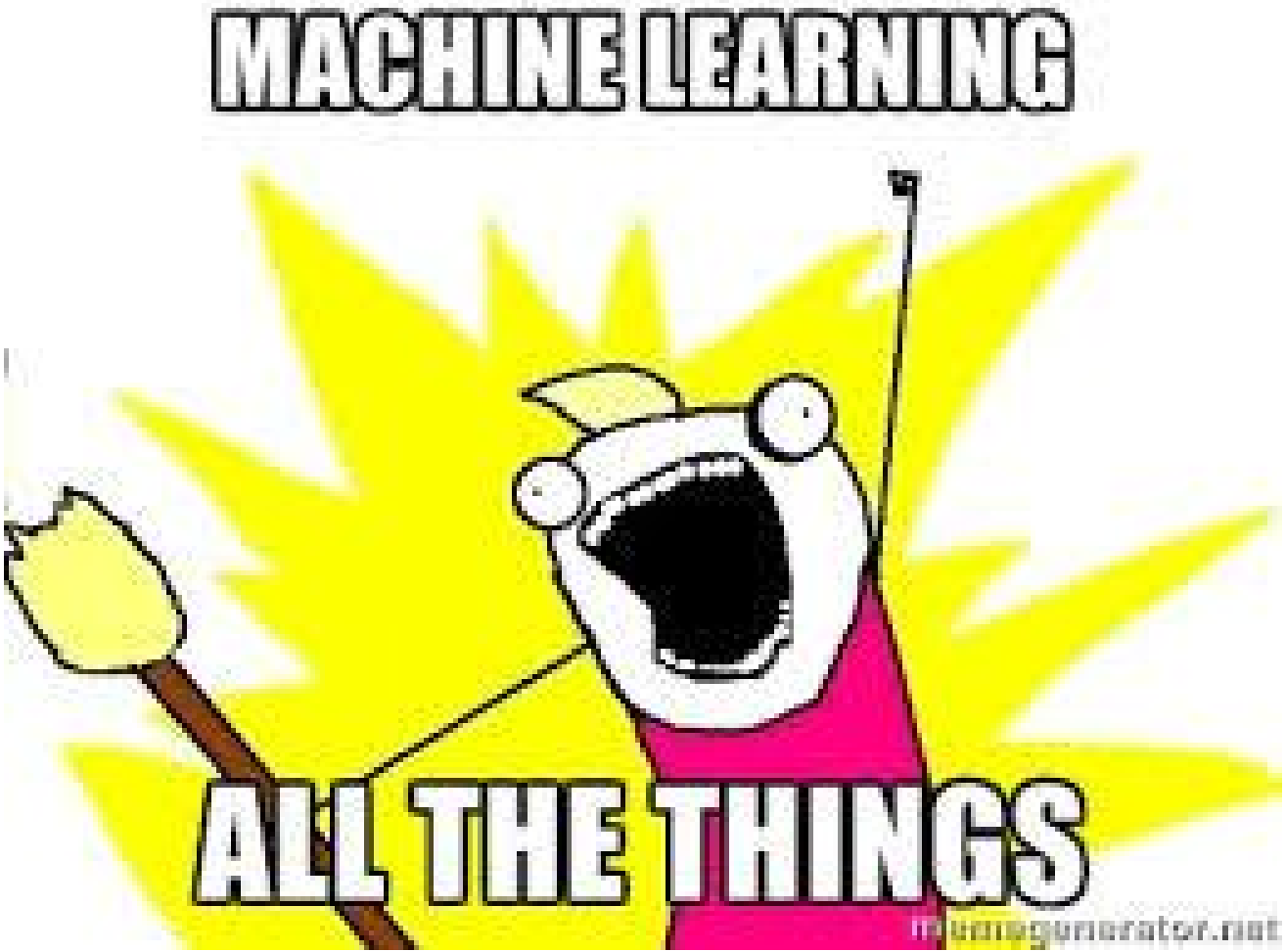
Some function f:
Requests → Classes



Predicting Request Graphs

F(Request) =




MACHINE LEARNING
ALL THE THINGS

Solve the Machine Learning problem?
or the Failure Testing one?

Simplest thing that will work?

Falcor Path Mapping

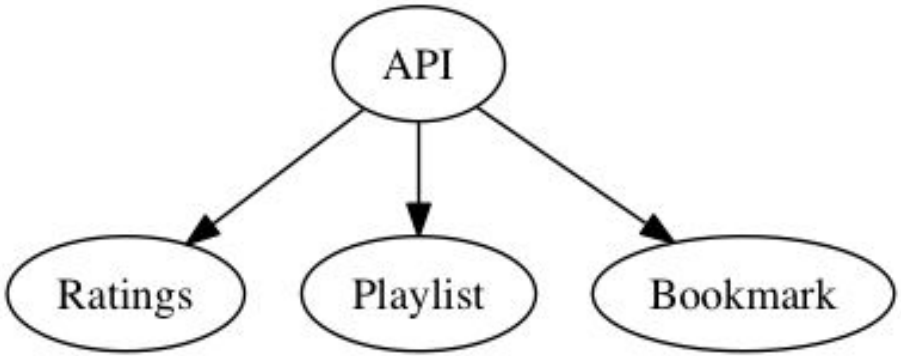
```
["bookmarks”, “recent”]

["playlist", 0, “name”]

["ratings"]
```

=>

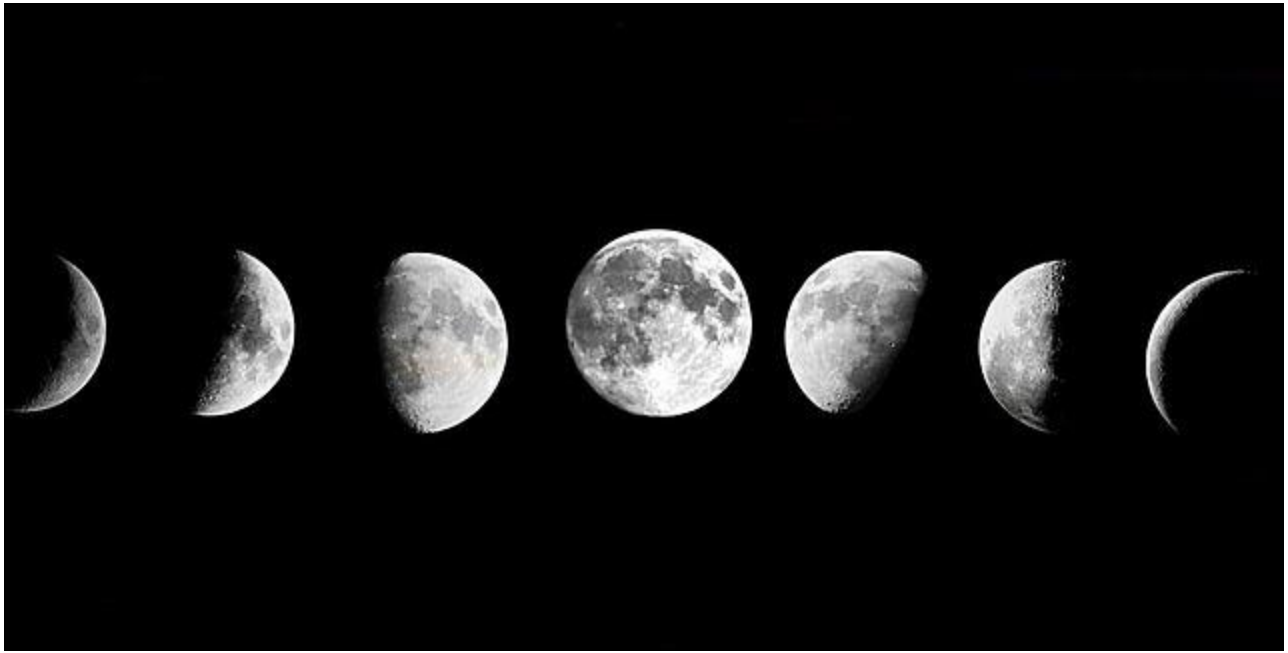
“bookmarks,playlist,ratings”



Lesson 3

Adapt the theory to the reality

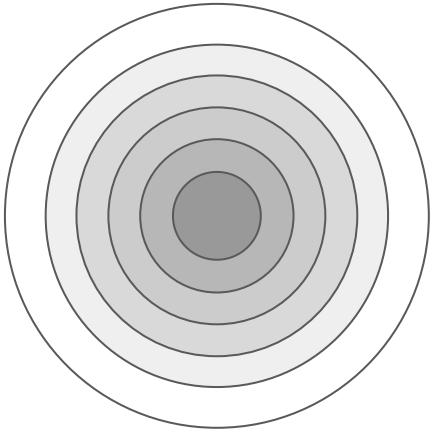
Many moons passed...



Does it work?

YES!

Case study: “Netflix AppBoot”



Services	~100
Search space (executions)	2^{100} (1,000,000,000,000,000,000,000,000,000,000)
Experiments performed	200
Critical bugs found	11

Future Work

Search prioritization

Richer lineage collection

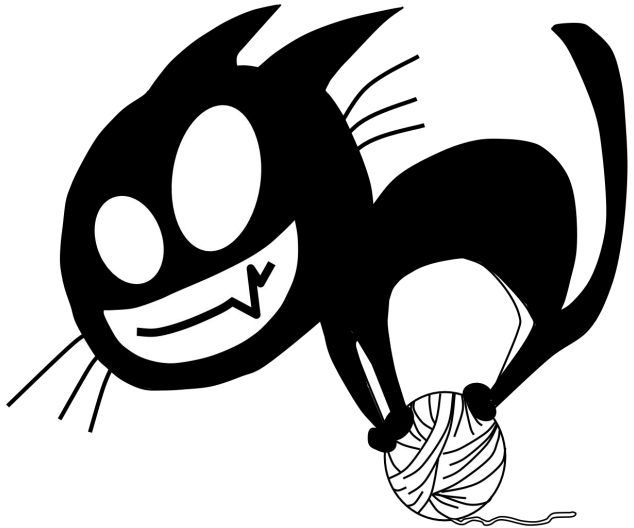
Exploring temporal interleavings

Richer device metrics

Request class creation

Better experiment selection

DISORDERLY



LABS

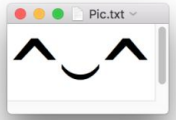
Current Team

Peter Alvaro Principal Investigator

Peter Alvaro is an Assistant Professor of Computer Science at UC Santa Cruz. He earned his PhD at UC Berkeley, where he was advised by Joe Hellerstein.

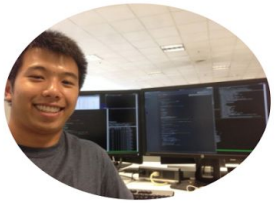
Kamala Aspiring Ml Wizard

Kamala started her PhD at UCSC in Fall, 2015. Her interests include reasoning about large scale distributed systems and applied machine learning, specifically how and when we might be able to apply machine learning effectively to understand complex systems better.



Kathryn Dahlgren Resident Koder Kat

Kathryn is a PhD student in Computer Science at UCSC. Her interests orbit research and developments in databases and distributed systems.



Tuan Kohd Wizard In Training

Tuan is a CS Ph.D student at UCSC, whose interests are in distributed systems and machine learning

Nikhil Kini Fault Injector

Operator on the intersection of logic, statistical relational learning, and distributed systems.

Ashutosh Code Wrangler

Ashutosh is a M.S. student at U.C. Santa Cruz, interested in databases, distributed computing and machine learning.

Read more about Ashutosh.

GREMLIN INC.

Breaking Things on Purpose

```
root@0a3037ae2bb6:/src/install# which gremlin
/usr/bin/gremlin
root@0a3037ae2bb6:/src/install# gremlin help
Usage: gremlin COMMAND [command-specific-options]

Type "gremlin help COMMAND" for more details:

  attack        # Run a new gremlin attack
  help          # List commands and display help
  rollback      # Interrupt an active attack, or revert the last impact.
  status        # Show the status of all gremlins or a specific attack.
  syscheck      # Run a system check.
  version       # Show version information for the gremlin binary.

root@0a3037ae2bb6:/src/install# gremlin help attack
Usage: gremlin attack TYPE [type-specific-options]

Type "gremlin help attack TYPE" for more details:

  blackhole     # An attack which drops all matching network traffic
  cpu           # An attack which consumes CPU resources
  latency       # An attack which adds latency to all matching network traffic
  memory        # An attack which consumes memory
  packet_loss   # An attack which introduces packet loss to all matching network traffic

root@0a3037ae2bb6:/src/install# gremlin attack cpu
Running cpu gremlin with guid 'b571bf60-7fa9-11e6-b029-a21b8ed525eb' for 15 seconds on 1 core
Attack on cpu_1 completed successfully
Attack successfully completed
root@0a3037ae2bb6:/src/install#
```

Gremlin API

gremlins	Show/Hide | List Operations | Expand Operations
users	Show/Hide | List Operations | Expand Operations
daemon	Show/Hide | List Operations | Expand Operations
clients	Show/Hide | List Operations | Expand Operations
orgs	Show/Hide | List Operations | Expand Operations
install	Show/Hide | List Operations | Expand Operations
executions	Show/Hide | List Operations | Expand Operations
attacks	Show/Hide | List Operations | Expand Operations

DELETE	/attacks
GET	/attacks
GET	/attacks/active
GET	/attacks/completed
POST	/attacks/new
DELETE	/attacks/{guid}
GET	/attacks/{guid}
GET	/attacks/{guid}/executions

[BASE URL: / , API VERSION: v1]

ERROR {...}

ATTACKS | CLIENTS | USERS | kolton | Halt All

Create Attack

Create a new attack.

Active Attacks

View active attacks.

Schedules

View scheduled attacks.

COMING SOON

Engagement

Test your pager and alerts.

COMING SOON

Red Team vs. Blue Team

The Red Team attacks, the Blue team defends!

COMING SOON

DiRT

Run a large scale Disaster Recovery Test.

CREATE ATTACK

Create or schedule a new attack.

Step 1: When will this attack run?

Now | Later | Randomly

Start: 9:00 am End: 5:00 pm

Runs at most 1 per day.

Days: M T W Th F S Su

Step 2: Choose your Gremlin

- blackhole
- latency
- packet_loss
- cpu
- memory

An attack which adds latency to all matching network traffic

Step 3: Customize the impact

ms	How long to delay ingress packets (millis)
port	Only impact traffic on this port
device	Impact traffic over this network interface
www.google.com	Only impact traffic to these hostnames
ipaddress(es)	Only impact traffic to these IP addresses
length	The length of the attack (seconds)

Step 4: Target Selection

Exact | Match | Random

Regular Expression: foo-service.*

The failure will be experienced on these hosts.

Cancel | Attack

ATTACKS

View all active and completed attacks. Halt active attacks. Re-run completed attacks.

Active Attacks

Automatically refresh

Search

Gremlin	Stage	Started	Length	Target	Args
cpu	Running	2 minutes ago	5 minutes	i-0aa77114902991cd4	

Completed Attacks

Search

Gremlin	Stage	Ended	Length	Target	Args
cpu	Successful	4 minutes ago	2 minutes	i-0aa77114902991cd4	1
latency	Successful	a day ago	30 seconds	172.31.36.163,172.31.30.111	www.google.com
latency	Successful	a day ago	15 seconds	172.31.30.111,172.31.36.163	www.google.com
blackhole	Aborted	2 days ago	2 minutes	172.31.36.163	service.gremlininc.com
packet_loss	Successful	2 days ago	15 seconds	172.31.36.163	50 www.google.com

Lessons

Work backwards from what you know

Meet in the middle

Adapt the theory to the reality

Academia + Industry

~~Academia + Industry~~

Academia ✖ Industry

Thank You!

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