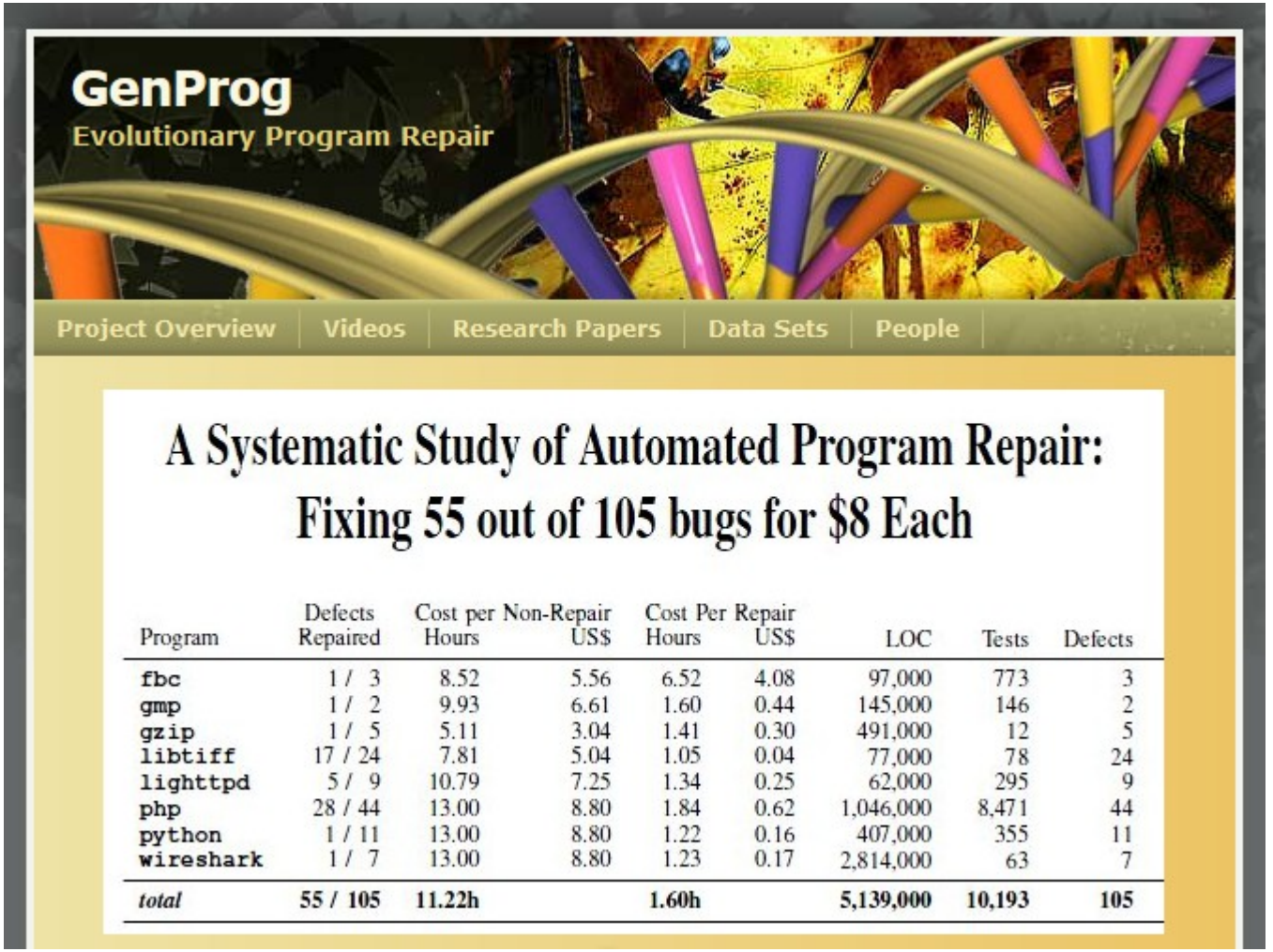
Automated Program Repair



A Systematic Study of Automated Program Repair: Fixing 55 out of 105 bugs for $8 Each

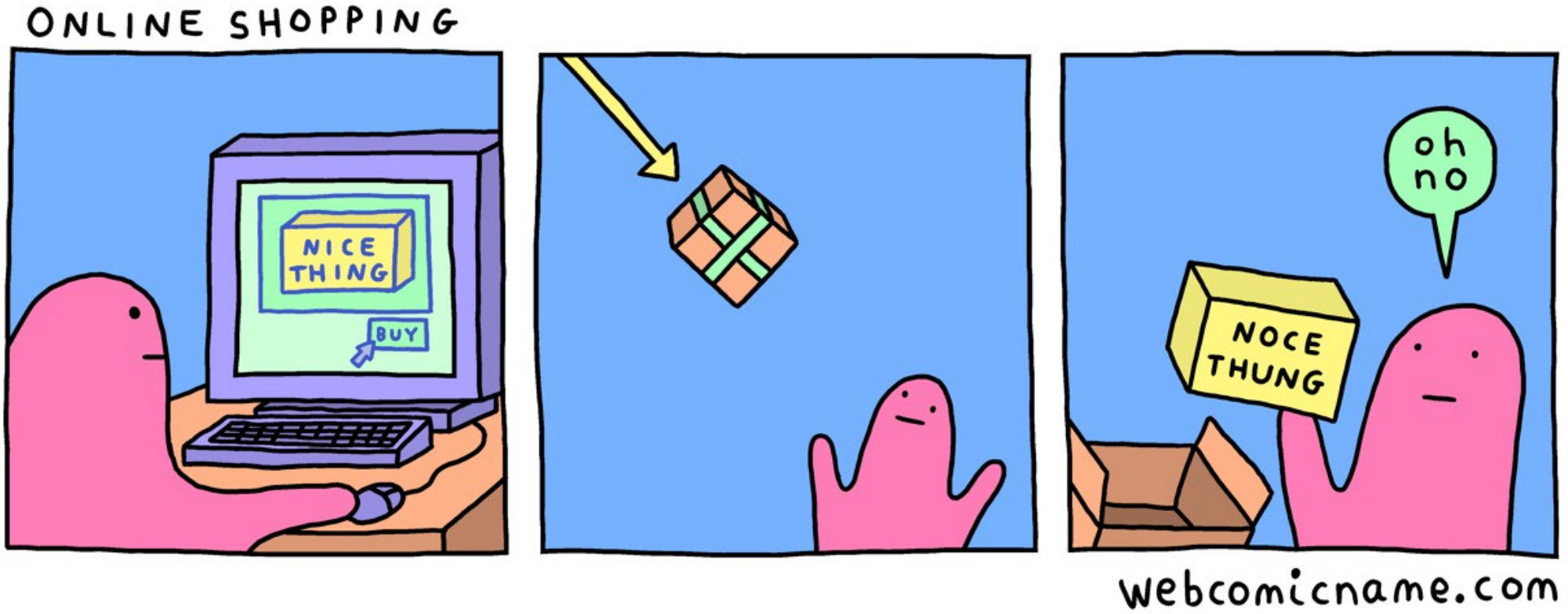
Program	Defects Repaired	Cost per Non-Repair Hours	Cost per Non-Repair US$	Cost Per Repair Hours	Cost Per Repair US$	LOC	Tests	Defects
`fbc`	1 / 3	8.52	5.56	6.52	4.08	97,000	773	3
`gmp`	1 / 2	9.93	6.61	1.60	0.44	145,000	146	2
`gzip`	1 / 5	5.11	3.04	1.41	0.30	491,000	12	5
`libtiff`	17 / 24	7.81	5.04	1.05	0.04	77,000	78	24
`lighttpd`	5 / 9	10.79	7.25	1.34	0.25	62,000	295	9
`php`	28 / 44	13.00	8.80	1.84	0.62	1,046,000	8,471	44
`python`	1 / 11	13.00	8.80	1.22	0.16	407,000	355	11
`wireshark`	1 / 7	13.00	8.80	1.23	0.17	2,814,000	63	7
total	**55 / 105**	**11.22h**		**1.60h**		**5,139,000**	**10,193**	**105**

The Never-Ending Story

- Today we will use recent advances in automated program repair to touch on all of the **lecture topics** from this course

Speculative Fiction

- What if large, trusted companies paid strangers online to find and fix their normal and critical bugs?



Microsoft Security Response Center

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Microsoft Security Bounty Programs

Print Email Share

[illegible] hackers, researchers! Want to help us protect customers, making some of our most popular products better? And earn money doing so? Step right up...

Microsoft is now offering direct cash payments in exchange for reporting certain types of vulnerabilities and exploitation techniques.

In 2002, we pioneered [illegible] Computing initiative to [illegible] commitment to doing what we believe best helps improve our customers' computing experience. In the years since, we introduced the Security Development Lifecycle (SDL) process to build more secure technologies. We also championed Coordinated Vulnerability Disclosure (CVD), formed industry collaboration programs such as MAPP and MSVR, and created the BlueHat Prize to encourage research into defensive technologies. Our new bounty programs add fresh depth and flexibility to our existing community outreach programs. Having these bounty programs provides a way to harness the collective intelligence and capabilities of security researchers to help further protect customers.

The following programs will launch on June 26, 2013:

1. **Mitigation Bypass Bounty.** Microsoft will pay up to $100,000 USD for truly novel exploitation techniques against protections built into the latest version of our operating system (Windows 8.1 Preview). Learning about new exploitation techniques earlier helps Microsoft improve security by leaps, instead of capturing one vulnerability at a time as a traditional bug bounty alone would. *TIMEFRAME: ONGOING*

2. **BlueHat Bonus for Defense.** Additionally, Microsoft will pay up to $50,000 USD for defensive ideas that accompany a qualifying Mitigation Bypass submission. Doing so highlights our continued support of defensive technologies and provides a way for the research community to help protect more than a billion computer systems worldwide. *TIMEFRAME: ONGOING (in conjunction with the Mitigation Bypass Bounty).*

3. **Internet Explorer 11 Preview Bug Bounty.** Microsoft will pay up to $11,000 USD for

Featured Video

Trustworthy Comput
Jonathan Ness, and
introduce new boun
researchers.

About the pro

Mitigation Bypass B
for Defense Guideli

Internet Explorer 11
Guidelines

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New Bounty Progra
information on bou

Heart of Blue Gold -

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For Security Researchers

Bug Bounty Wall of Fame

For Customers: Reporting Suspicious Emails

Customers who think they have received a Phishing email, please learn more about phishing at **https://cms.paypal.com/us/cgi-bin/marketingweb?cmd=_render-content&content_ID=security/hot_security_topics**, or forward it to: spoof@paypal.com

For Customers: Reporting All Other Concerns

Customers who have issues with their PayPal Account, please visit: **https://www.paypal.com/cgi-bin/helpscr?cmd=_help&t=escalateTab**

For Professional Researchers: Bug Bounty Program

Our team of dedicated security professionals works vigilantly to help keep customer information secure. We recognize the important role that security researchers and our user community play in also helping to keep PayPal and our customers secure. If you discover a site or product vulnerability please notify us using the guidelines below.

Program Terms

Please note that your participation in the Bug Bounty Program is voluntary and subject to the terms and conditions set forth on this page ("Program Terms"). By submitting a site or product vulnerability to PayPal, Inc. ("PayPal") you acknowledge that you have read and agreed to these Program Terms.

These Program Terms supplement the terms of PayPal User Agreement, the PayPal Acceptable Use Policy, and any other agreement in which you have entered with PayPal (collectively "PayPal Agreements"). The terms of those PayPal Agreements will apply to your use of, and participation in, the Bug Bounty Program as if fully set forth herein. If there is any inconsistency exists between the terms of the PayPal Agreements and these Program Terms, these Program Terms will control, but only with regard to the Bug Bounty Program.

You can jump to particular sections of these Program Terms by using the following links:

- **Responsible Disclosure Policy**
- **Eligibility Requirements**
- **Bug Submission Requirements and Guidelines**

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AT&T Bug Bounty Program

Intro

Already a Member?

Sign In or Join Now

Welcome to the AT&T Bug Bounty Program! This program encourages and rewards contributions by developers and security researchers who help make AT&T's online environment more secure. Through this program AT&T provides monetary rewards and/or public recognition for security vulnerabilities responsibly disclosed to us.

The following explains the details of the program. To immediately start submitting your AT&T security bugs, please visit the Bug Bounty submittal page.

Guidelines

The AT&T Bug Bounty Program applies to security vulnerabilities found within AT&T's public-facing online environment. This includes, but not limited to, websites, exposed APIs, and mobile applications.

A security bug is an error, flaw, mistake, failure, or fault in a computer program or system that impacts the security of a device, system, network, or data. Any security bug may be considered for this program; however, it must be a new, previously unreported, vulnerability in order to be eligible for reward or recognition. Typically the in-scope submissions will include high impact bugs; however, any vulnerability at any severity might be rewarded.

Bugs which directly or indirectly affect the confidentiality or integrity of user data or privacy are prime candidates for reward. Any security bug, however, may be considered for a reward. Some characteristics that are considered in "qualifying" bugs include those


Microsoft Security Response Center
Search Microsoft.co
Personal
Business
Email
forgot?
Password
forgot?
Log In
Sign Up
PayPal
Buy
Sell
Transfer
upport > AT&T Bug Bounty Program > Intro
AT&T Bug Bounty Program
Intro
Rewards
Report Bug
Hall of Fame
PRINT
EMAIL
(Raise hand if true)
I have used software produced by Microsoft, PayPal, AT&T, Facebook, Mozilla, Google *or* Youtube.
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Bug Bounties

- If you trust your triage and code review processes, anyone can submit a candidate bug report or candidate patch
- **Bug Bounties** combine **defect reporting and triage** with **pass-around code review**
- Finding, fixing and ignoring bugs are all so expensive that it is now (~2013+) economical to pay untrusted strangers to submit candidate defect reports and patches

Bug Bounties and Large Companies

- “We get hundreds of reports every day. Many of our best reports come from people whose English isn't great – though this can be challenging, it's something we work with just fine and we have paid out over $1 million to hundreds of reporters.”
  - Matt Jones, Facebook Software Engineering

Bug Bounties and Small Companies

- Only 38% of the submissions were true positives (harmless, minor or major): "Worth the money? Every penny." - Colin Percival, Tarsnap

For this reason, Tarsnap has a series of *bug bounties*. Similar to the bounties offered by Mozilla and Google, the Tarsnap bug bounties provide an opportunity for people who find bugs to win cash. Unlike those bounties, the Tarsnap bug bounties aren't limited to security bugs. Depending on the type of bug and when it is reported, different bounties will be awarded:

Bounty value	Pre-release bounty value	Type of bug
$1000	$2000	A bug which allows someone intercepting Tarsnap traffic to decrypt Tarsnap users' data.
$500	$1000	A bug which allows the Tarsnap service to decrypt Tarsnap users' data.
$500	$1000	A bug which causes data corruption or loss.
$100	$200	A bug which causes Tarsnap to crash (without corrupting data or losing any data other than an archive currently being written).
$50	$100	Any other non-harmless bugs in Tarsnap.
$20	$40	Build breakage on a platform where a previous Tarsnap release worked.
$10	$20	"Harmless" bugs, e.g., cosmetic errors in Tarsnap output or mistakes in source code comments.
$5	$10	A patch which significantly improves the clarity of source code (e.g., by refactoring), source code comments (e.g., by rewording or adding text to clarify something), or documentation. (Merely pointing to something and saying "this is unclear" doesn't qualify; you must provide the improvement.)
$1	$2	Cosmetic errors in the Tarsnap source code or website, e.g., typos in website text or source code comments. Style errors in Tarsnap code qualify here, but usually not style errors in upstream code (e.g., libarchive).

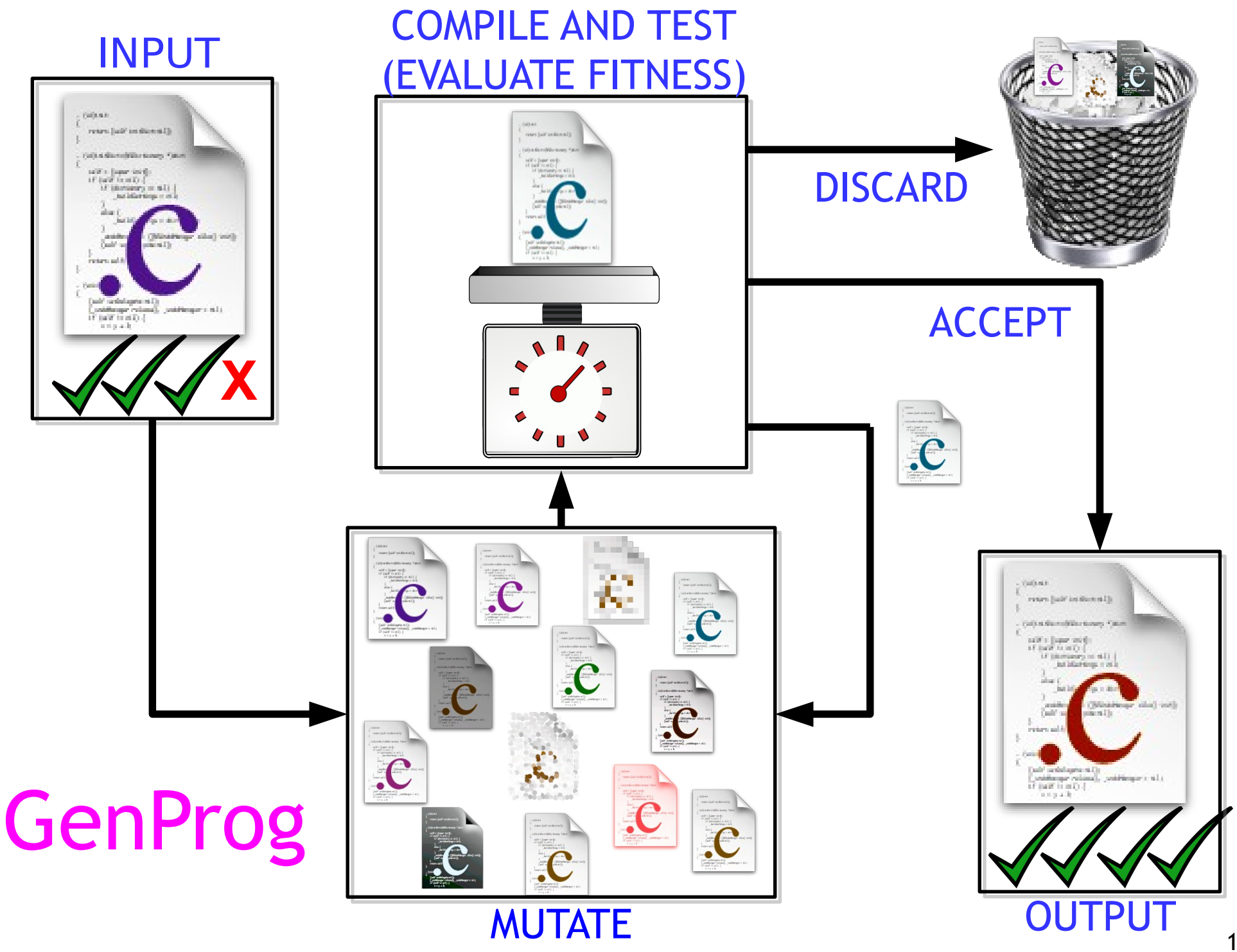
A Modest Proposal

- Using techniques from this class
- We can automatically find and fix defects
  - Rather than, or in addition to, paying strangers
- Given a program …
  - Source code, binary code, etc.
- … and evidence of a bug …
  - Passing and failing tests, crashes, etc.
- … fix that bug.
  - Create a textual patch (pull request)

How could that work?

- Many faults can be localized to a small area
  - Even if your program is a million lines of code, **fault localization** can narrow it to 10-100 lines
- Many defects can be fixed with small changes
  - **Mutation** (test metrics) can generate candidate patches from simple edits
  - **A search-based software engineering** problem
- Can use regression **testing** (inputs and oracles, continuous integration) to assess patch quality

[Weimer et al. *Automatically Finding Patches Using Genetic Programming*. Best Paper Award. IFIP TC2 Manfred Paul Award. SIGEVO "Humies" Gold Award. Ten-Year Impact Award.]


INPUT
COMPILE AND TEST
(EVALUATE FITNESS)
DISCARD
ACCEPT
MUTATE
OUTPUT
GenProg

Minimizing Patches

- A GenProg patch may contain extraneous edits
  - “close();” vs. “close(); x = x + 0;”
  - Both pass all tests, but …
- Longer patches are harder to read
- Extraneous edits may only appear safe because of weak test suites: avoid unneeded churn
- After the repair search, use **delta debugging** (hypothesis testing) to find a passing 1-minimal edit subset

Name	Subjects	Tests	Bugs	Notes
AFix	2 Mloc	–	8	Concurrency, guarantees
ARC	–	–	–	Concurrency, SBSE
ARMOR	6 progs.	–	3 + –	Identifies workarounds
Axis	13 progs.	–	–	Concurrency, guarantees, Petri nets
AutoFix-E	21 Kloc	650	42	Contracts, guarantees
CASC	1 Kloc	–	5	Co-evolves tests and programs
ClearView	Firefox	57	9	Red Team quality evaluation
Coker Hafiz	15 Mloc	–	7 / –	Integer bugs only, guarantees
Debroy Wong	76 Kloc	22,500	135	Mutation, fault localization focus
Demsky *et al.*	3 progs.	–	–	Data struct consistency, Red Team
FINCH	13 tasks	–	–	Evolves unrestricted bytecode
GenProg	5 Mloc	10,000	105	Human-competitive, SBSE
Gopinath *et al.*	2 methods.	–	20	Heap specs, SAT
Jolt	5 progs.	–	8	Escape infinite loops at run-time
Juzi	7 progs.	–	20 + –	Data struct consistency, models
PACHIKA	110 Kloc	2,700	26	Differences in behavior models
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Minimizing Costs

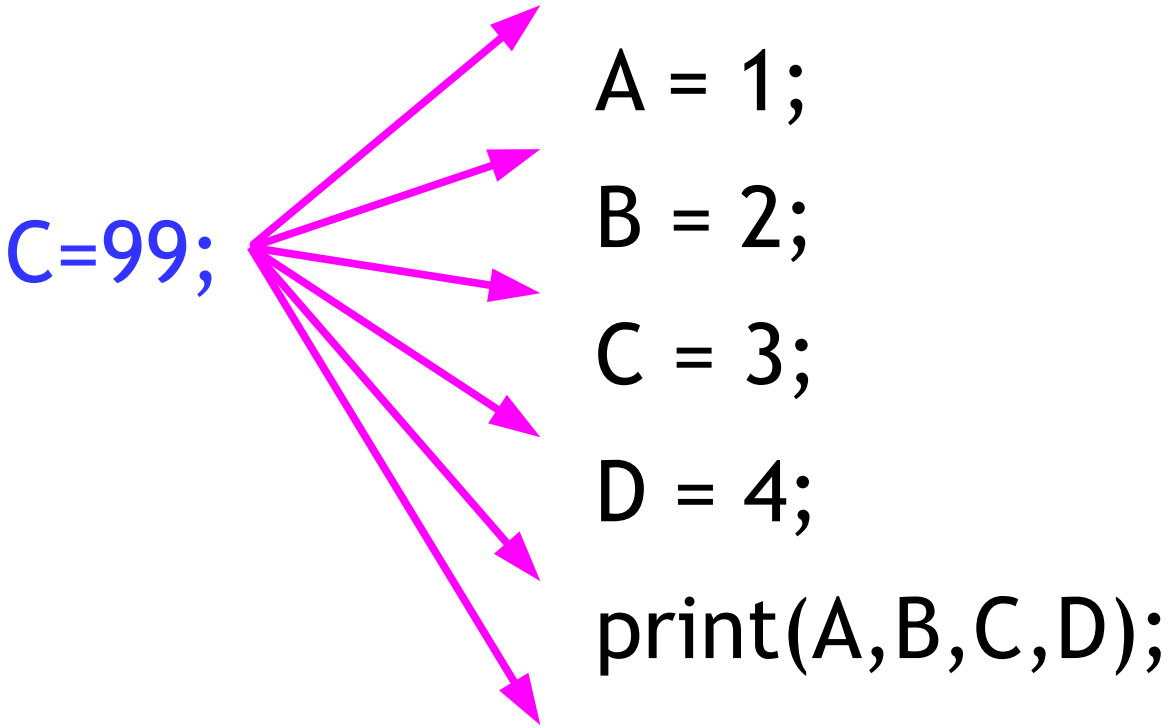
- Can stop generating candidate mutants when a valid repair is found, parallelize in the cloud

  [Le Goues et al. *A Systematic Study of Automated Program Repair: Fixing 55 out of 105 bugs for $8 Each.*]

- Each repair must pass the entire test suite
  - Running tests is the dominant cost of automated program repair
  - Use test suite prioritization and minimization
  - Stop evaluating as soon as a single test fails
    - Even one failure → Not a valid repair!

Can We Avoid Testing?

- If P1 and P2 are semantically equivalent they must have the same functional test behavior
- Consider this insertion:



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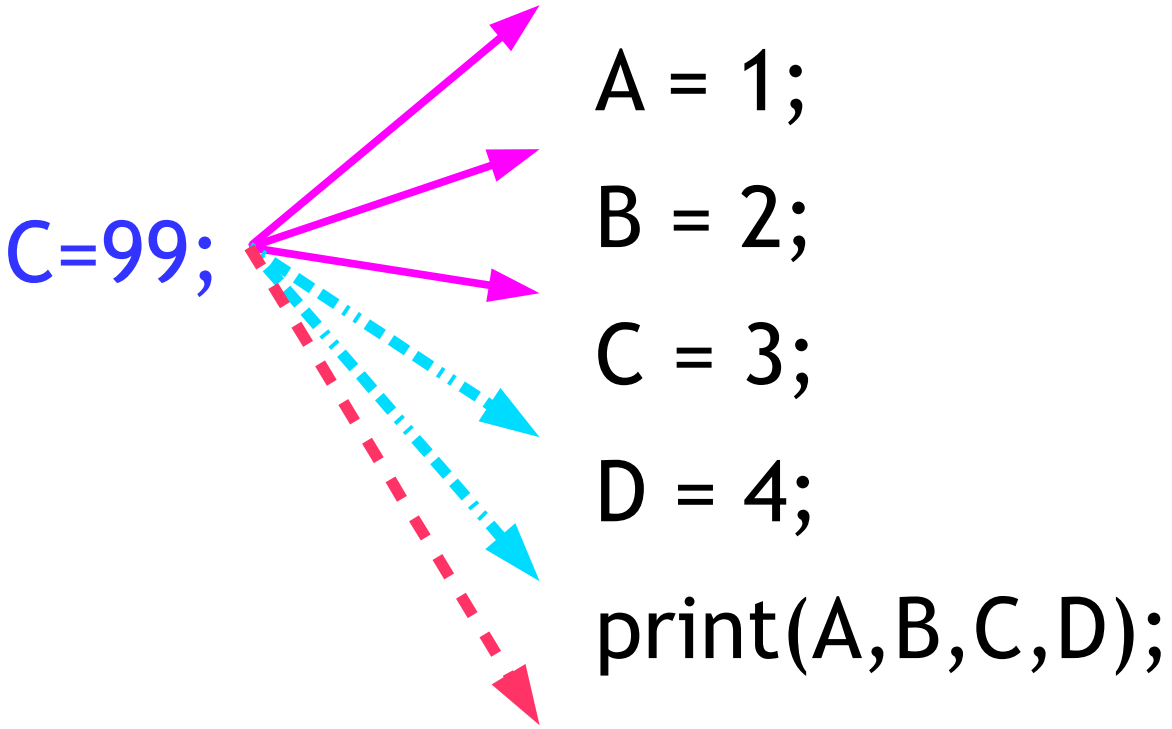


Static Analysis

- If we had a cheap way to approximately decide if two programs are equivalent
  - We wouldn't need to test any candidate patch that is equivalent to a previously-tested patch

    (Cluster or quotient the search space into equivalence classes with respect to this relation)
- We use **static analysis** (like a dataflow analysis for dead code or constant propagation) to decide this: 10x reduction in search space

[Weimer et al. *Leveraging Program Equivalence for Adaptive Program Repair: Models and First Results.*]

Design Patterns

- In mutation testing, the mutation operators are based on common human mistakes
- Instead, use human edits or **design patterns**
  - "Add a null check" or "Use a singleton pattern"
- Mine 60,000 human-written patches to learn the 10 most common fix templates
  - Resulting approach fixes 70% more bugs
  - Human study of non-student developers (n=68): such patches are 20% more acceptable

[Kim et al. *Automatic Patch Generation Learned from Human-Written Patches.* Best paper award.]

Not Trivial: Agronomy and Genetics

- This Nobel Peace Prize winner is described as the father of modern agriculture and the green revolution. Bruce Alberts, National Academy of Sciences President, said of him: “Some credit him with saving more human lives than any other person in history.” He is credited with saving over a billion people worldwide from starvation.

Not Trivial: Death

- Rank these causes of death in the US for 2017 (most recent CDC data available):
  - Accidents (unintentional injuries)
  - Assault (homicide)
  - Heart disease
  - Influenza and pneumonia
- Extra credit: One of these is about 20-100x more common than another. Identify that pairing.

Not Trivial: Death Details

2017 CDC (Table D, Page 12, extract)

https://www.cdc.gov/nchs/data/nvsr/nvsr68/nvsr68_06-508.pdf

Cause of death (based on ICD–10)		Rank[1]	Deaths
All causes		...	2,179,857
Diseases of heart	(I00–I09,I11,I13,I20–I51)	1	508,485
Malignant neoplasms	(C00–C97)	2	465,679
Chronic lower respiratory diseases	(J40–J47)	3	139,833
Accidents (unintentional injuries)	(V01–X59,Y85–Y86)	4	127,029
Cerebrovascular diseases	(I60–I69)	5	110,038
Alzheimer disease	(G30)	6	101,876
Diabetes mellitus	(E10–E14)	7	55,116
Influenza and pneumonia	(J09–J18)	8	43,397
Intentional self-harm (suicide)	(*U03,X60–X84,Y87.0)	9	38,106
Nephritis, nephrotic syndrome and nephrosis	(N00–N07,N17–N19,N25–N27)	10	35,191
Chronic liver disease and cirrhosis	(K70,K73–K74)	11	30,223
Septicemia	(A40–A41)	12	30,198
Essential hypertension and hypertensive renal disease	(I10,I12,I15)	14	24,465
Assault (homicide)	(*U01–*U02,X85–Y09,Y87.1)	20	5,747

Not Trivial: World History

- This world leader is alleged to have said “A single death is a tragedy; a million deaths is a statistic” during the 1943 Tehran conference when Churchill objected to an early opening of a second front in France.

Psychology: Emotions vs. Math

- N=1111 (!) adult participants were shown math problems to assess their numeracy

(half were shown the numbers flipped)

	Result	
	Rash Got Better	Rash Got Worse
Patients who did use the new skin cream	223	75
Patients who did not use the new skin cream	107	21

What result does the study support?

- People who used the skin cream were more likely to get better than those who didn't.
- People who used the skin cream were more likely to get worse than those who didn't.

Identity-Protection Cognition Thesis

- First, 59% of participants got it wrong
- Second, they tracked political beliefs
- Third, they also gave the same math problems (same numbers, etc.), but reworded the treatment as a city passing a gun ban and the effect as crime decreasing (or not)
- Spoiler: highly-numerate people end up *more* vulnerable to bias

[Kahan et al. *Motivated Numeracy and Enlightened Self-Government*. Behavioral Public Policy.]

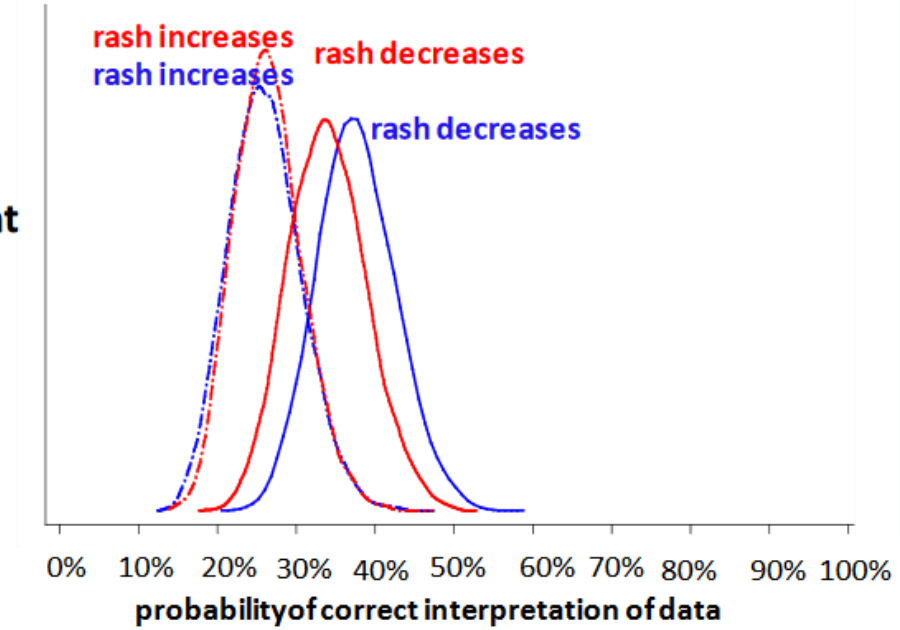
Liberal Democrat (-1 SD on Conservrepub) Conservative Republican (+1 SD on Conservrepub)

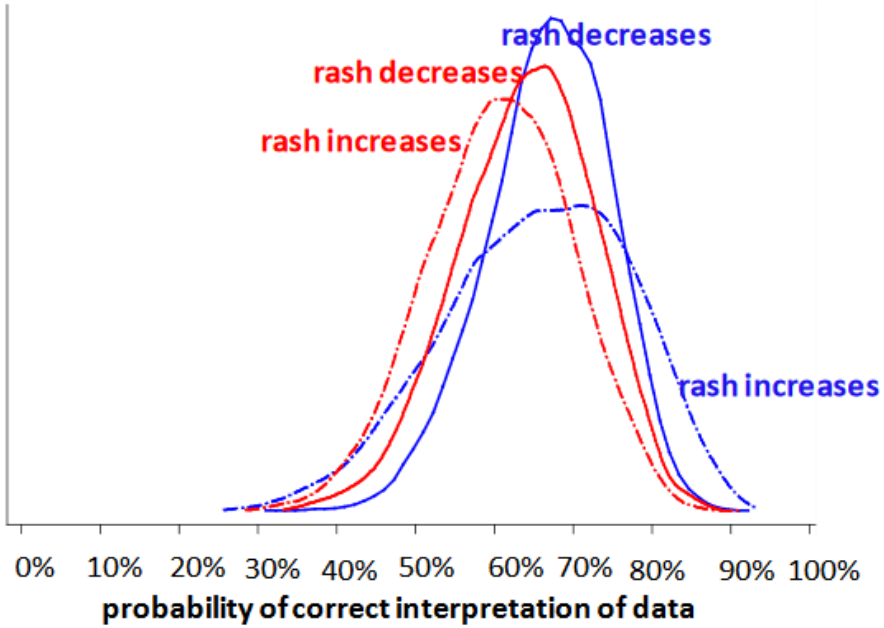
low numeracy = 3 correct/ high numeracy = 7 correct

Low numeracy

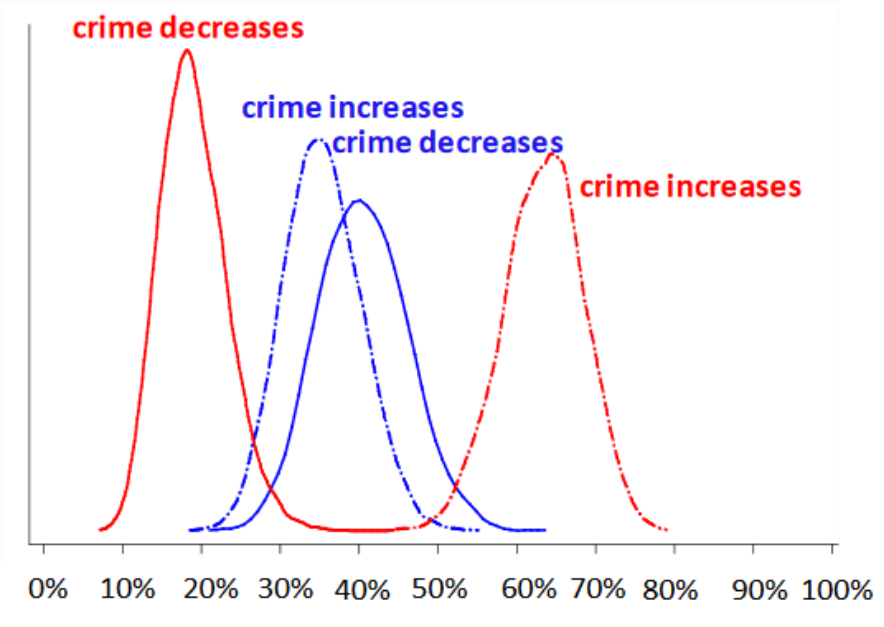
High numeracy

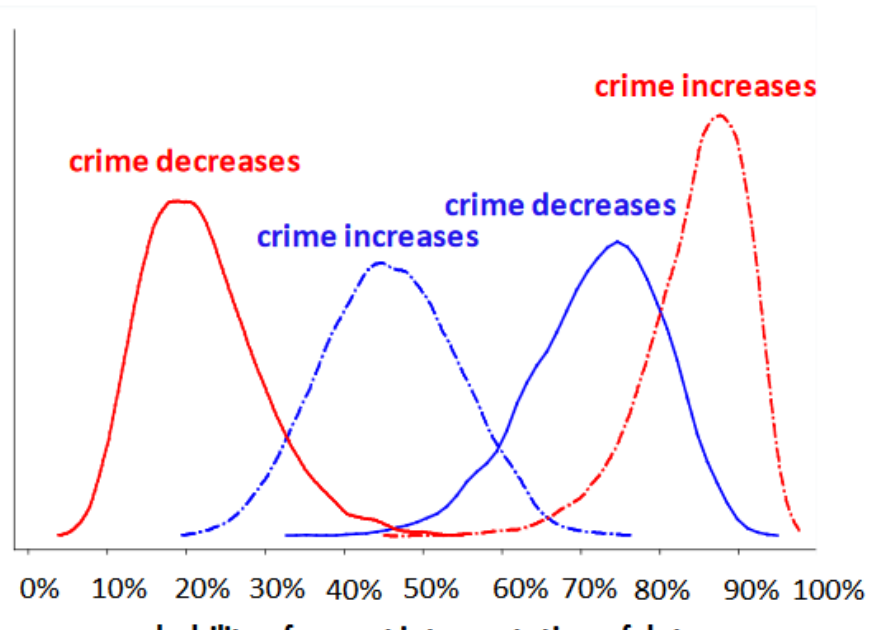
Skin treatment





Gun ban



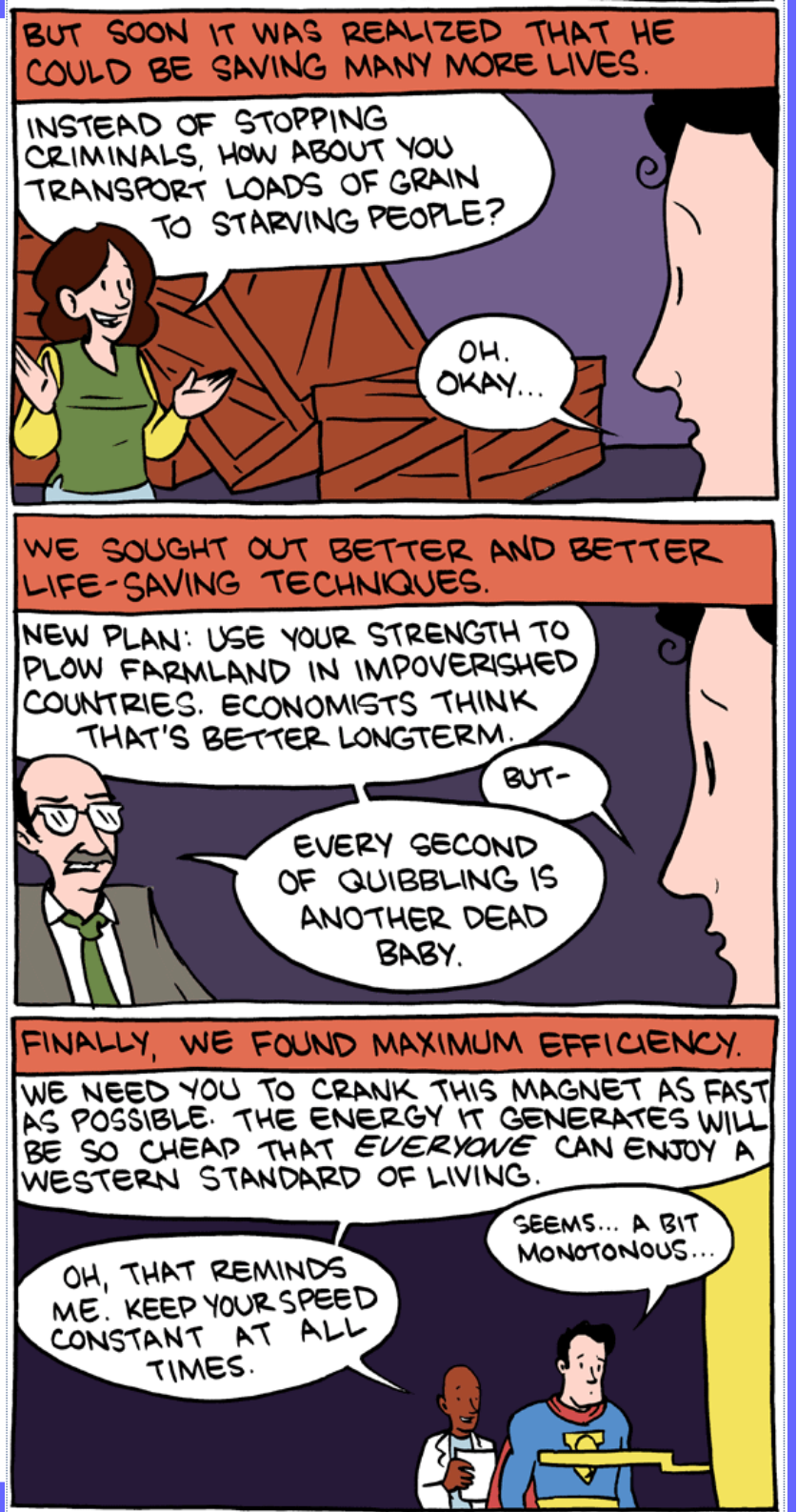


- Risk is “likelihood of P happening” * “cost if P happens”
- Amhdalh's Law is “time spent on P” * “improvement possible to P”
- But we can't do math …

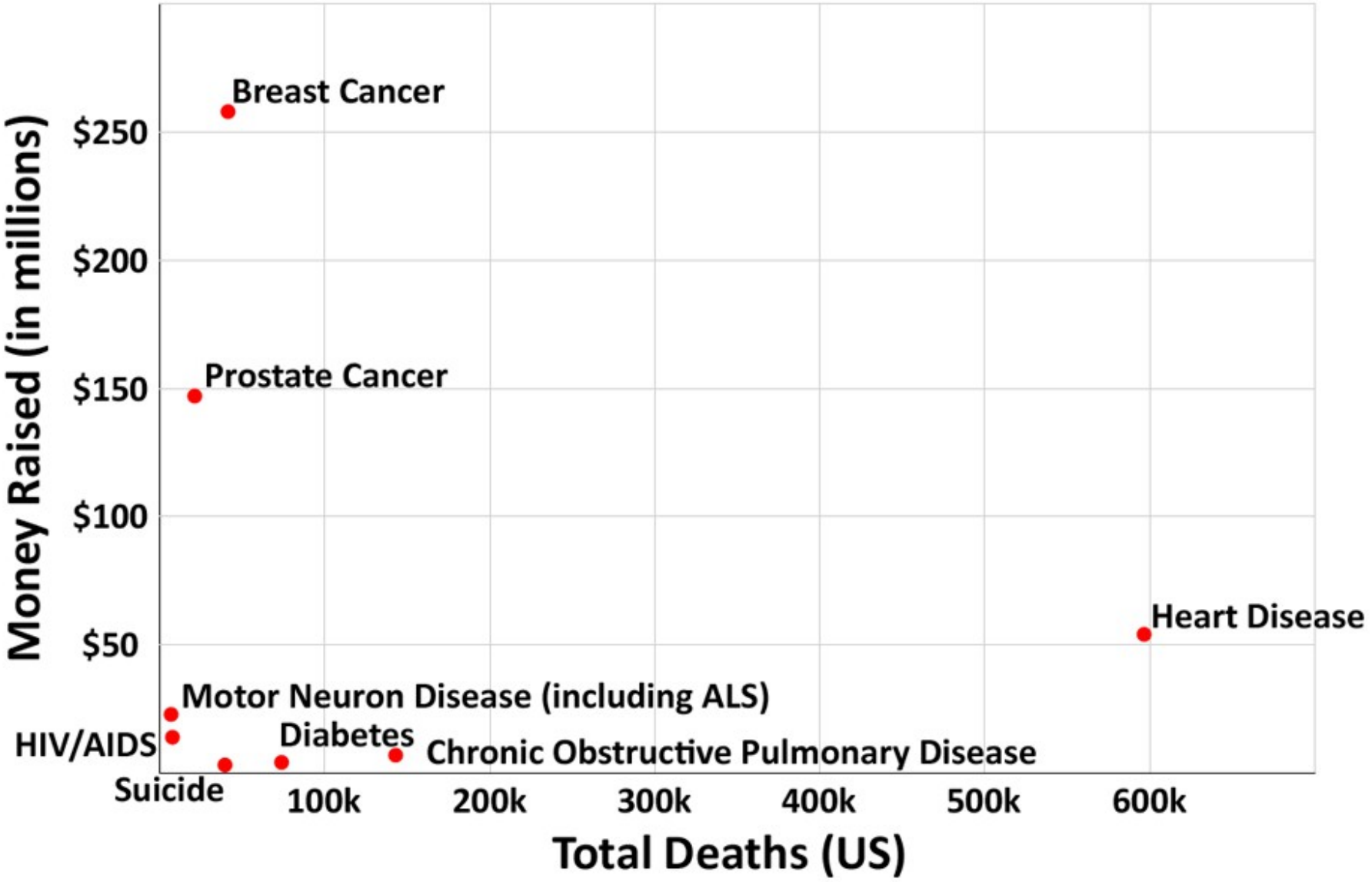
[https://www.smbc-comics.com/?id=2305]

Super Opportunity Cost

- If you are really interested in the greatest good for the greatest number, don't focus on muggings
- Dually, focus on muggings if you like, but don't lie to yourself about what you are doing
  - Local importance to you vs. global importance overall



WHERE WE DONATE VS. DISEASES THAT KILL US



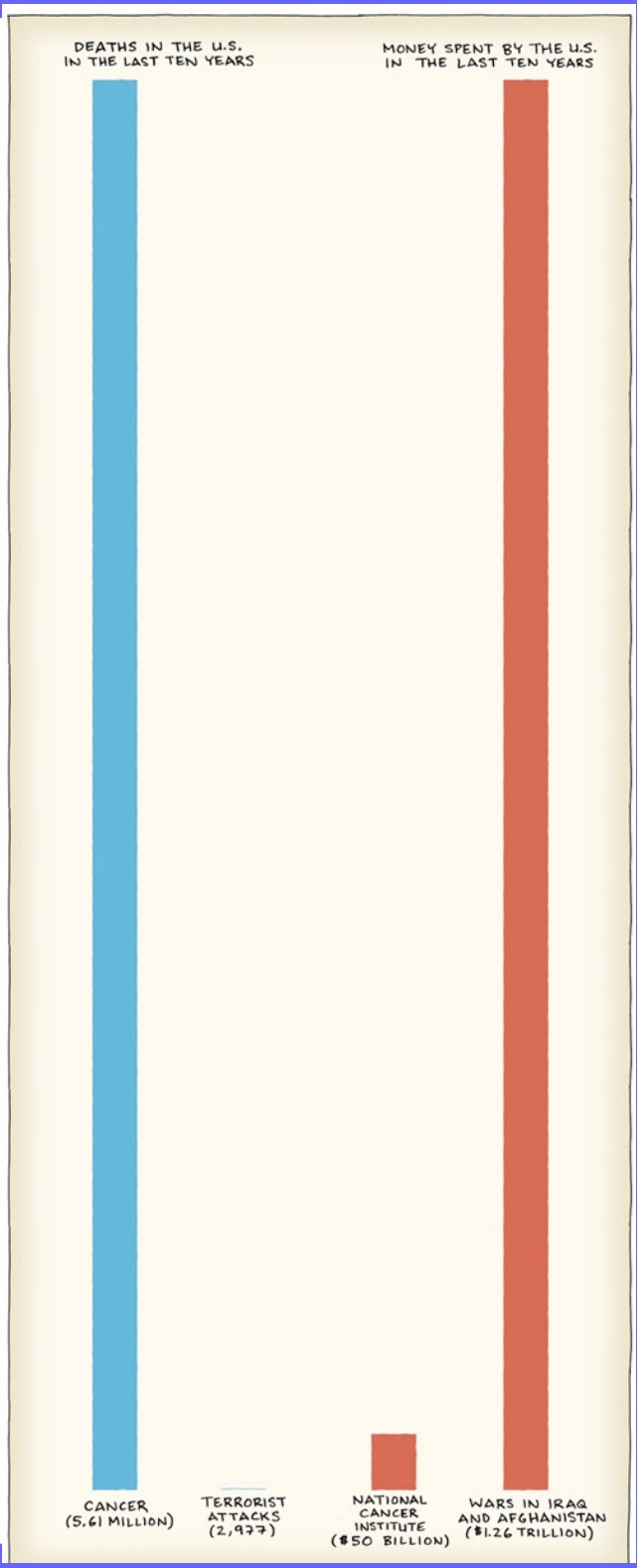
Sources: CDC, 2011; Komen Race for the Cure, 2012; Movember, 2013; Jump Rope for Heart, 2013; ALS Ice Bucket Challenge, 2014; Ride to End Aids, 2013; Fight for Air Climb, 2013; Step Out: Walk to Stop Diabetes, 2013; Out of Darkness Overnight Walk, 2014.

Aside: Metrics

- But perhaps we have fewer deaths due to X because we are spending money to ameliorate X (e.g., diabetes, malaria, etc.)
  - Can we do "lives saved vs. money spent"?
- Yes! Large organizations use metrics such as the **disability-adjusted life year** (DALY), a measure of overall disease burden, expressed as the number of years lost due to ill-health, disability or early death
  - See **effective altruism** and similar movements

Cognitive Bias Conclusion

- I am not saying you should not fight cancer or that you should not be liberal or conservative
  - All have good points
- I am saying that you should **figure out what you want** and then **correctly evaluate candidate actions** in that light
  - Do things because you want to, not because you made a mistake



Relationship with Mutation Testing

- This program repair approach is a dual of **mutation testing**
  - This suggests avenues for cross-fertilization and helps explain some of the successes and failures of program repair.

- Very informally:
  - PR Exists M in Mut. Forall T in Tests. M(T)
  - MT Forall M in Mut. Exists T in Tests. Not M(T)

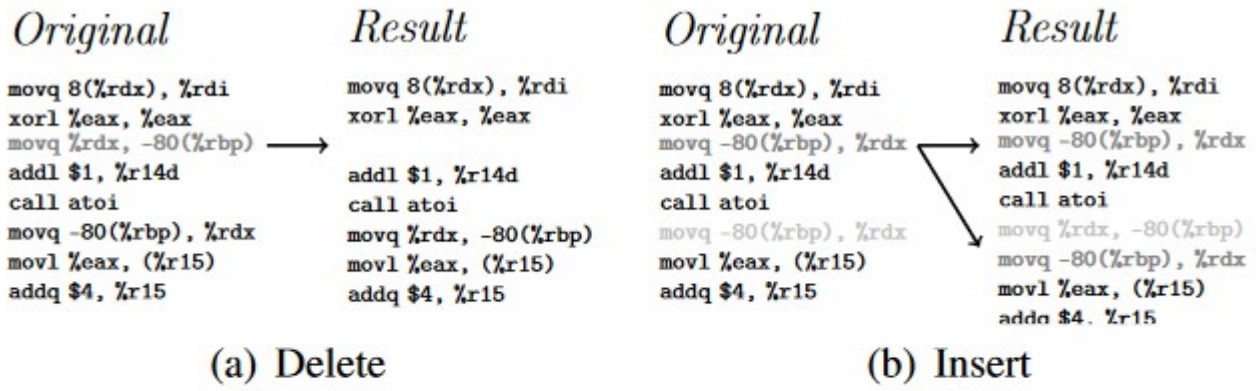
Idealized Formulation

Ideally, mutation testing takes a program that **passes** its test suite and requires that **all** mutants based on human **mistakes** from the **entire** program that are not equivalent **fail** at least one test.

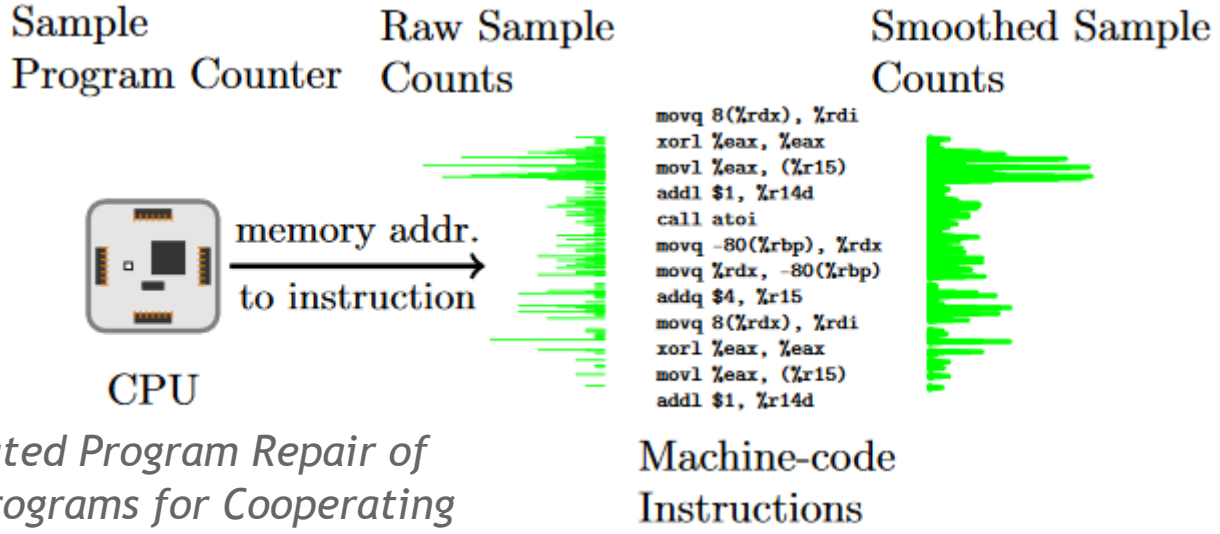
By contrast, program repair takes a program that **fails** its test suite and requires that **one** mutant based on human **repairs** from the fault **localization** only be found that **passes** all tests.

No Source Code Needed

- Can repair assembly or binary programs to support **multi-language projects**



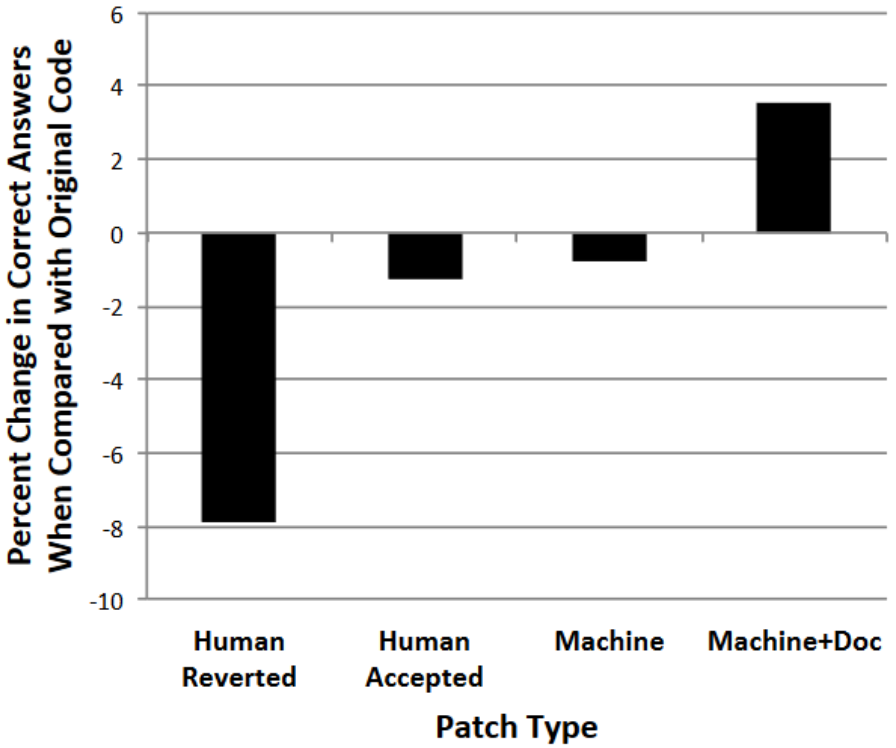
- Use **sampling-based profiling** for fault localization

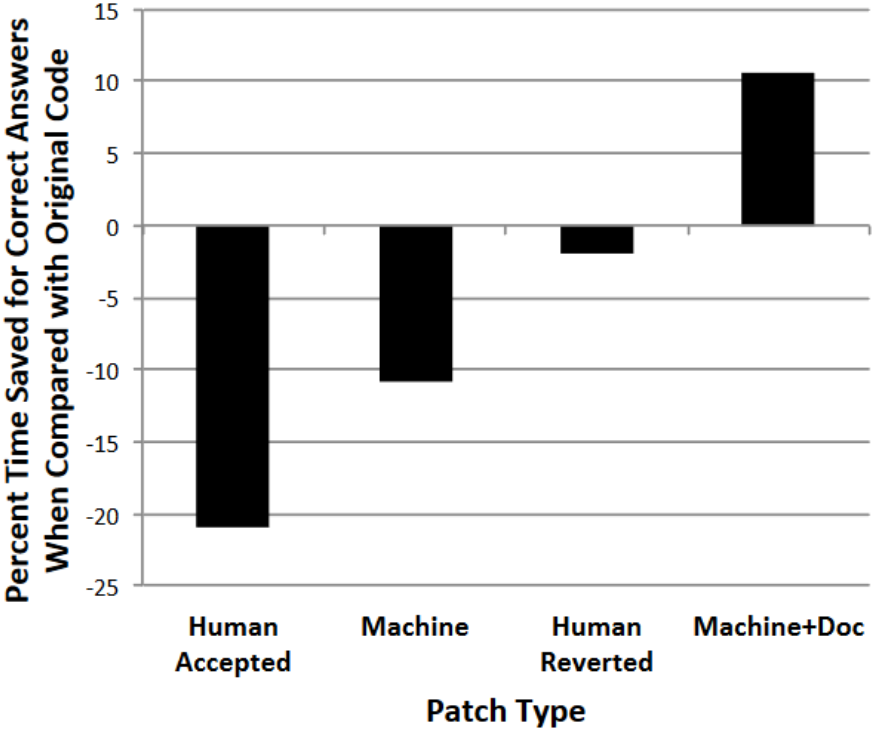


[Schulte et al. *Automated Program Repair of Binary and Assembly Programs for Cooperating Embedded Devices.*]

Can Humans Use These Patches?

- Synthesize "What" comments for generated patches (**design for maintainability**)
  - **Test input generation** constraints → English
  - Human study (N=150): "With docs → Yes!"





[Fry et al. *A Human Study of Patch Maintainability.*]

Human-Machine Partnerships

- What if your partner in **pair programming** were a machine that suggested patches?
  - Machine is driver, you are navigator/observer
  - In response to your feedback and characterization of program state, it suggests new patches
- You note "checkpoints" where at point *X*, test *Y* is running correctly (or variable *Z* is wrong)
- Human study of first-year grads (N=25):
  - Reduces debugging on 14/15 scenarios compared to singleton (~60% reduction over all 15)

[Xinrui Guo. *SmartDebug: An Interactive Debug Assistant for Java.*]

Concurrency Bugs

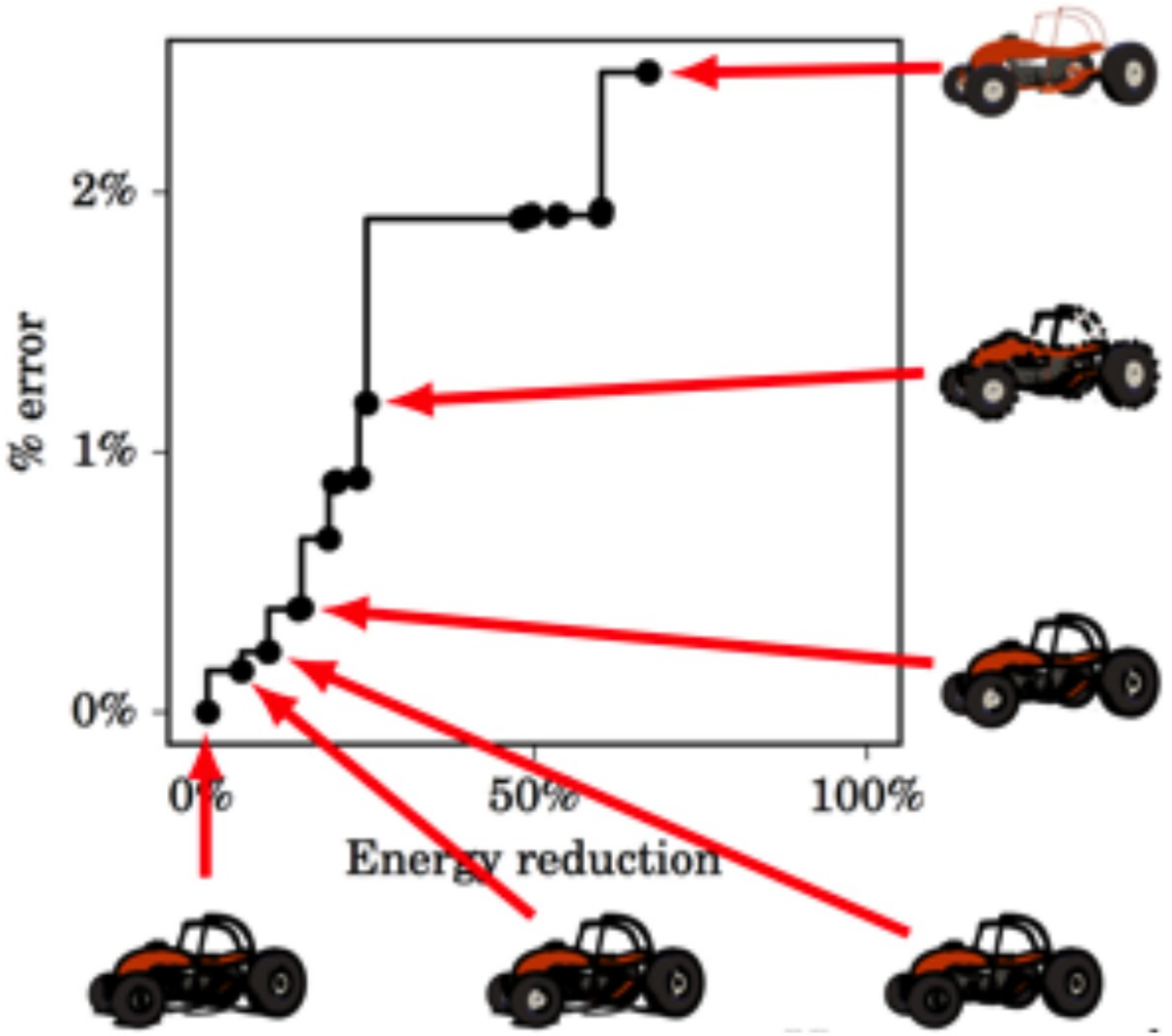
- So far we have required deterministic tests
- We can use a **dynamic analysis** like CHESS or Eraser to detect concurrency bugs
  - Look for two threads accessing *X*, one is a write
- Use special repair templates (e.g., always add paired lock()/unlock() calls)
- Fixes 6/8 historical single-variable atomicity violations in Apache, MySQL, Mozilla, etc.
  - Devs fixed 6/8 in 11 days each, on average
  - Union of humans and devs fixes all 8/8

[Jin et al. *Automated Atomicity-Violation Fixing.*]

Quality Defects

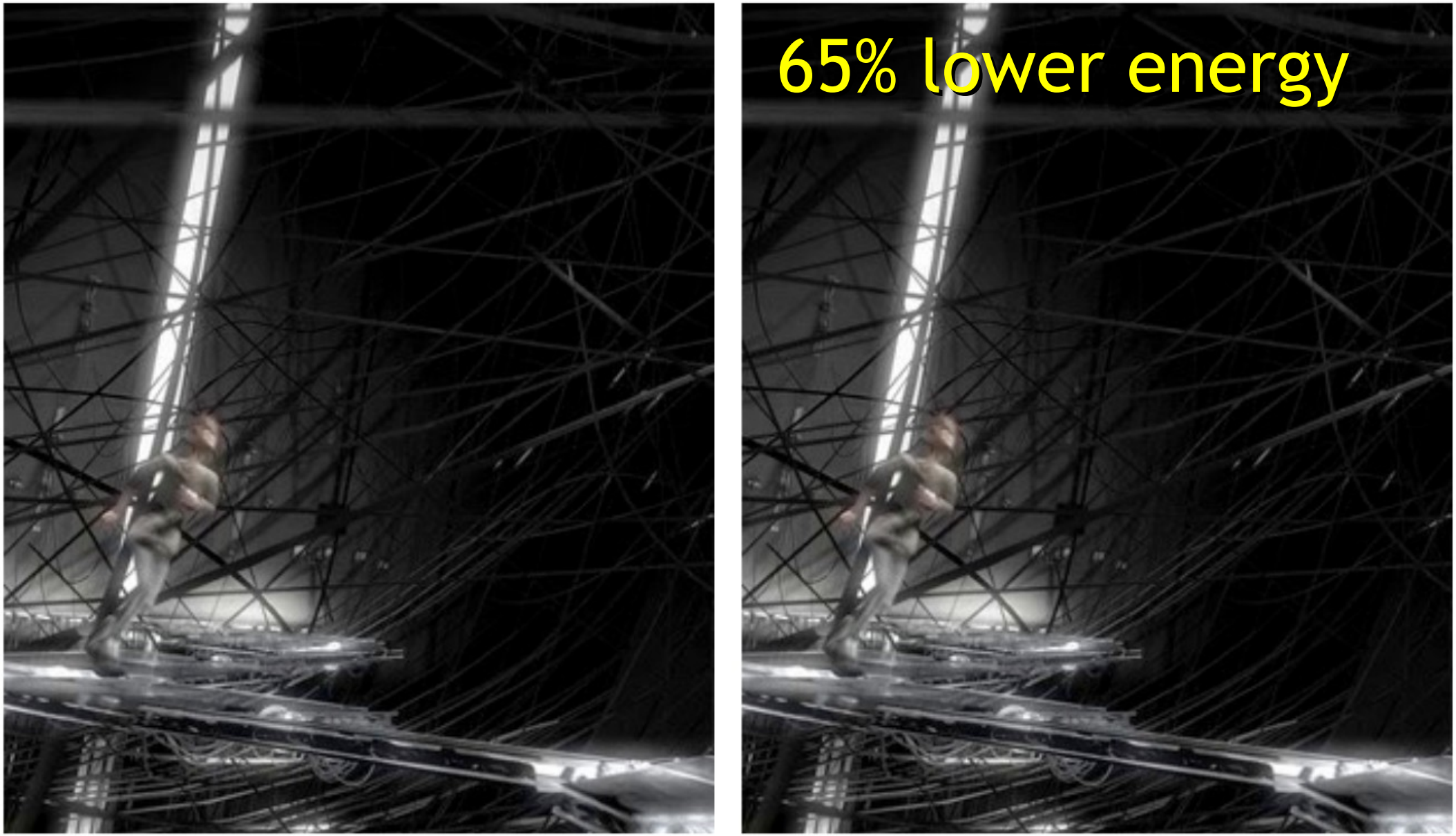
- What if the bug is that your program is too slow or too big or uses too much energy?
- We can also improve and trade-off **verifiable quality properties** (requirements)
  - cf. MP3 or JPG *lossy* compression: space vs. quality
- Candidates must pass all functional tests
- But we also measure quality properties of all passing candidates
- Present a Pareto frontier to help user explore alternative solutions to requirement conflicts

Automatically Exploring Tradeoffs In Conflicting Requirements



Can you spot the difference?

Can you spot the difference?



[Dorn et al. *Automatically exploring tradeoffs between software output fidelity and energy costs.*]

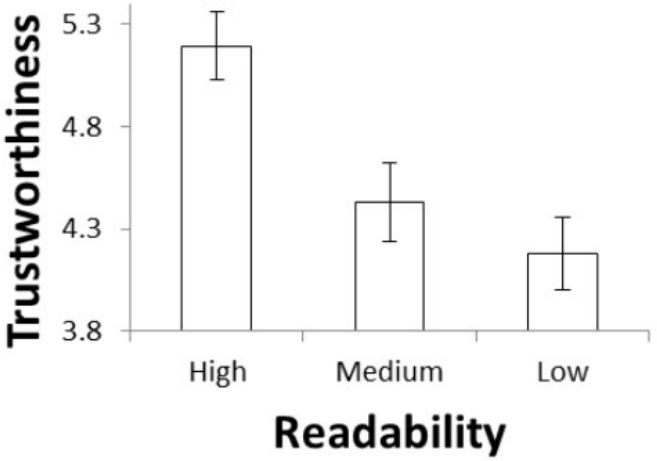
Code Inspection

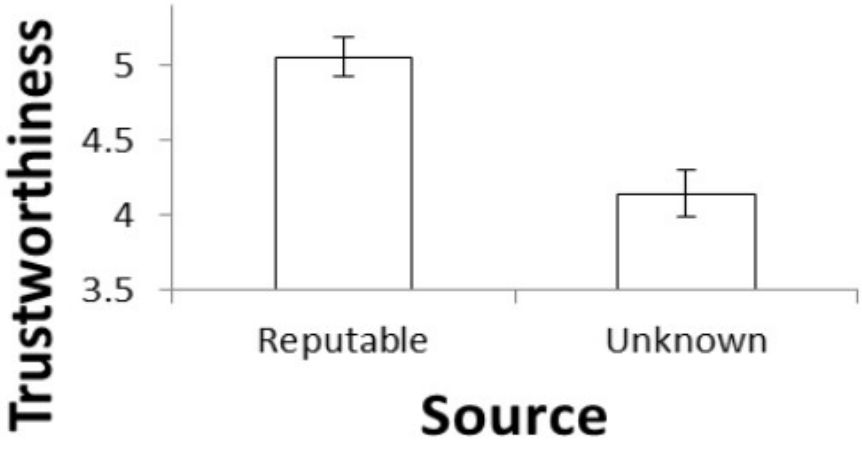
- What if we want to improve **code inspection**?
- Make many EvoSuite-generated unit tests
- Use a learned readability metric to rank them
  - Given two tests with equal coverage, humans agree with readability ranking 69% of the time
  - Recall difficulties with normative models
- Humans (n=30) are 14% faster when answering maintenance questions on readability-optimized tests (same level of accuracy)

[Daka et al. *Modeling Readability to Improve Unit Tests*. Best paper award.]

Human Brains and Subjectivity

- Trust is sometimes defined as a willingness to take on risk. How do **human brains perceive** and trust code from unknown sources? [Walter et al. *Developing a mechanism to study code trustworthiness.*]
- Cognitive Task Analysis of how readability and provenance relate to human trust (n=12 grads)
  - Take same code and degrade readability, etc.





“Wishes Come True, Not Free”

- Automated program repair, the whiny child:
  - “You only said I had to *get in* to the bathtub, you didn't say I had to wash.”
- The **specification** (tests) must encode **requirements** (cf. conflicts)
- GenProg's first webserver defect repair
  - 5 regression tests (GET index.html, etc.)
  - 1 bug (POST → remote security exploit)
  - GenProg's fix: remove POST functionality
  - (Adding a 6th test yields a high-quality repair.)

Requirements and Testing

- MIT Lincoln Labs evaluation of GenProg: sort
  - Tests: “the output of sort is in sorted order”
  - GenProg's fix: “always output the empty set”
  - (More tests yield a higher-quality repair. cf. design-by-contract pre- and post-conditions)
- Existing human-written tests suites implicitly assume the developers are reasonable humans
  - Unless you are outsourcing, you rarely test against “creative” for “adversarial” solutions or bugs
  - cf. “we're already good at this” denials, terminology conflicts

Measuring Quality via Tests

- Another GenProg example:
  - Tests: “compare yours.txt to trusted.txt”
  - GenProg's fix: “delete trusted.txt, output nothing”
- Canonical **perverse incentives** situation
  - Automated program repair optimizes the **metric**
  - “What you said” not “What you meant”
- Sleep forever to avoid CPU-usage penalties
- Always segfault to avoid bad output checks

[Weimer. *Advances in Automated Program Repair and a Call to Arms.*]

The Future

- Despite quality and trust concerns, some form of this is coming in the future (10-20 years?)
  - Already-demonstrated **productivity** gains
- What if “solve this one-line bug” became an atomic action in your lexicon?
  - The same way “complete this method call” or “sort” or “rename this variable” is today

Productive Imposters

- Old adage: What do you call someone who graduates last in a medical school class?
- Many worry: “I'm not as fast at coding”
- If most of SE is maintenance and 33-50% of bugs can be fixed automatically, the real in-demand skills are evaluating candidate fixes and eliciting and encoding requirements
  - The future of productivity: reading and talking
  - True for bug bounties or automated repair
  - This isn't really news (cf. first lectures …)

Should My Company Use It?

- As with any other **software development process** option (e.g., pair programming, Infer, 100% coverage goals, etc.) we estimate (or measure) costs and benefits
  - 2012: fix 50% of bugs, $8 each (vs. $20 for humans)
  - 2013: 3x cheaper, not counting cloud reductions
- Does not have to be used exclusively
  - Tools generate patches for simple bugs, freeing up creative human developer time for tougher issues
  - A fault tree analysis is possible, etc.

Fixing Bugs in Your Sleep: How Genetic Improvement Became an Overnight Success [2017]

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ABSTRACT

We present a bespoke live system in commercial use with self-improving capability. During daytime business hours it provides an overview and control for many specialists to simultaneously schedule and observe the rehabilitation process for multiple clients. However in the evening, after the last user logs out, it starts a self-analysis based on the day's recorded interactions. It generates test data from the recorded interactions for Genetic Improvement to fix any recorded bugs that have raised exceptions. The system has already been under test for over 6 months and has in that time identified, located, and fixed 22 bugs. No other bugs have been identified by other methods during that time. It demonstrates the effectiveness of simple test data generation and the ability of GI for improving live code.

1 INTRODUCTION

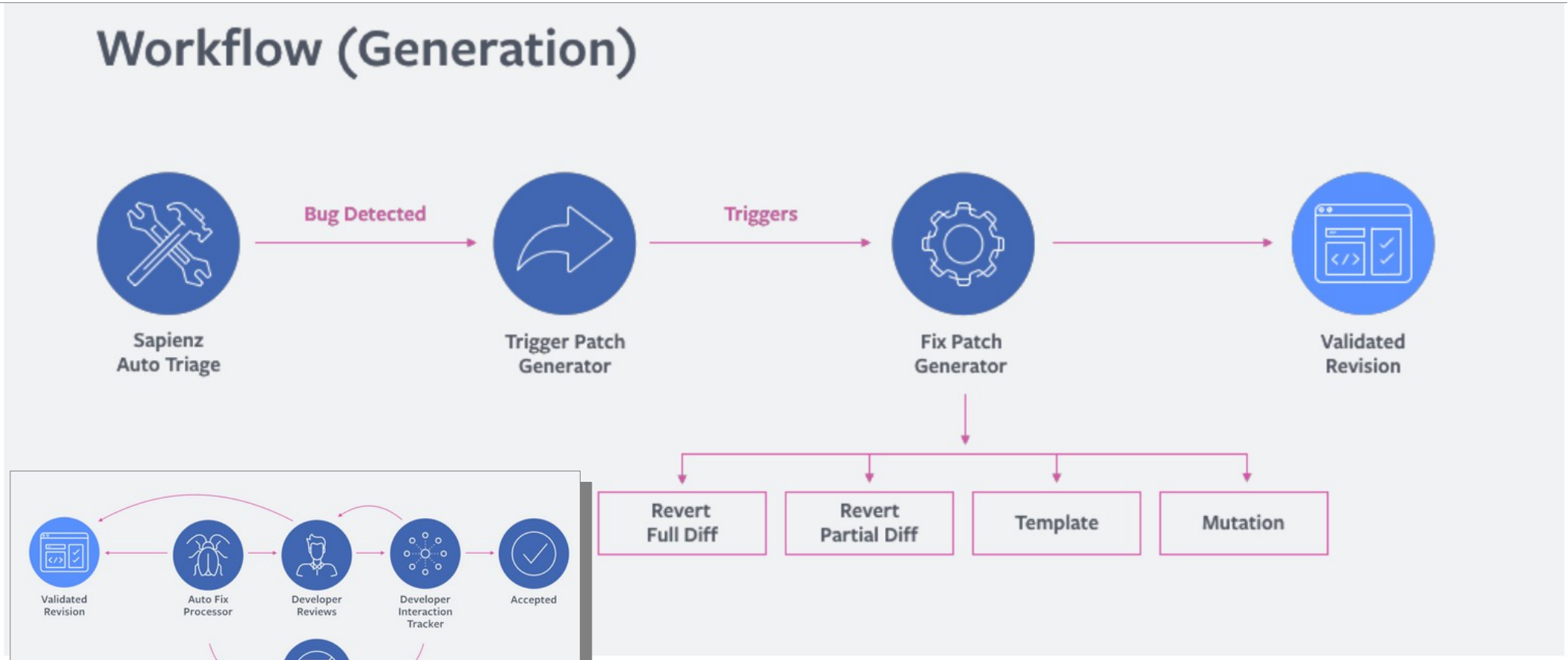
Genetic Improvement (GI) [38] is a growing area within Search Based Software Engineering (SBSE) [23, 24] which uses computational search methods to improve existing software. Despite its growth within academic research the practical usage of GI has not yet followed. Like with many SBSE applications, the software industry needs an incubation period for new ideas where they come to trust in outcomes and see those ideas as cost effective solutions. GI is in the ideal position to shorten that period for the latter as it presents a considerable cost decrease for the software life cycle's often most expensive part: maintenance [18, 34]. There are examples of software improved by GI being used and publicly available [31] which is impressive considering how young GI is as a field. In time it can be anticipated that we will see tools emerging

Facebook's SapFix [Sep 2018]

https://code.fb.com/developer-tools/finding-and-fixing-software-bugs-automatically-with-sapfix-and-sapienz/

Finding and fixing software bugs automatically with SapFix and Sapienz

When previously used human-designed templates don't fit, SapFix will attempt a mutation-based fix, whereby it performs small code modifications to the abstract syntax tree (AST) of the crash-causing statement, making adjustments to the patch until a potential solution is found.



"... the tool has successfully generated patches that have been accepted by human reviewers and pushed to production ..."

SapFix: Automated End-to-End Repair at Scale

- “We report our experience with SapFix: the first deployment of automated end-to-end fault fixing, from test case design through to deployed repairs in production code. We have used SapFix at Facebook to repair 6 production systems, each consisting of tens of millions of lines of code, and which are collectively used by hundreds of millions of people worldwide.”

  https://ieeexplore.ieee.org/document/8804442

Questions

- Exam 2

- Possible student-chosen lecture topic?