Testing – an odd optimization problem

Cap'n Robert Merkel

A-ha Me Hearties????

Why pirates???

Because we're going to go searching for buried treasure!

The search

- A chest of buried treasure somewhere on the islan
- No X on the map…

The rules

- One treasure chest
- Known size, shape, and orientation
- No information about location
  - equally likely to be anywhere on the island
- Only way to search – dig a hole.
- Minimize expected # of holes required.
  - The F-measure (because each failed attempt equals a flogging by the captain).

Plan #1

- Cap'n Rrrrt
  1. Choose a spot randomly.
  2. Dig there.
  3. If treasure found, stop,
  4. otherwise, back to step 1

Plan #2

- Captain Aaaaaart
  1. Choose *n* possible candidate places to dig.
  2. Choose the candidate *c* with the greatest distance from the nearest existing hole (maximin criterion)
  3. Dig at location *c*
  4. If treasure found, stop
  5. Otherwise, back to step 1.

Results

- Plan B - ~40% fewer holes than plan A.
- But what about Plan C, D, E…
- Tried many.
- Supplies of rum ran tragically low.
- Some of them were lower-overhead than plan B.
- Results were roughly the same.

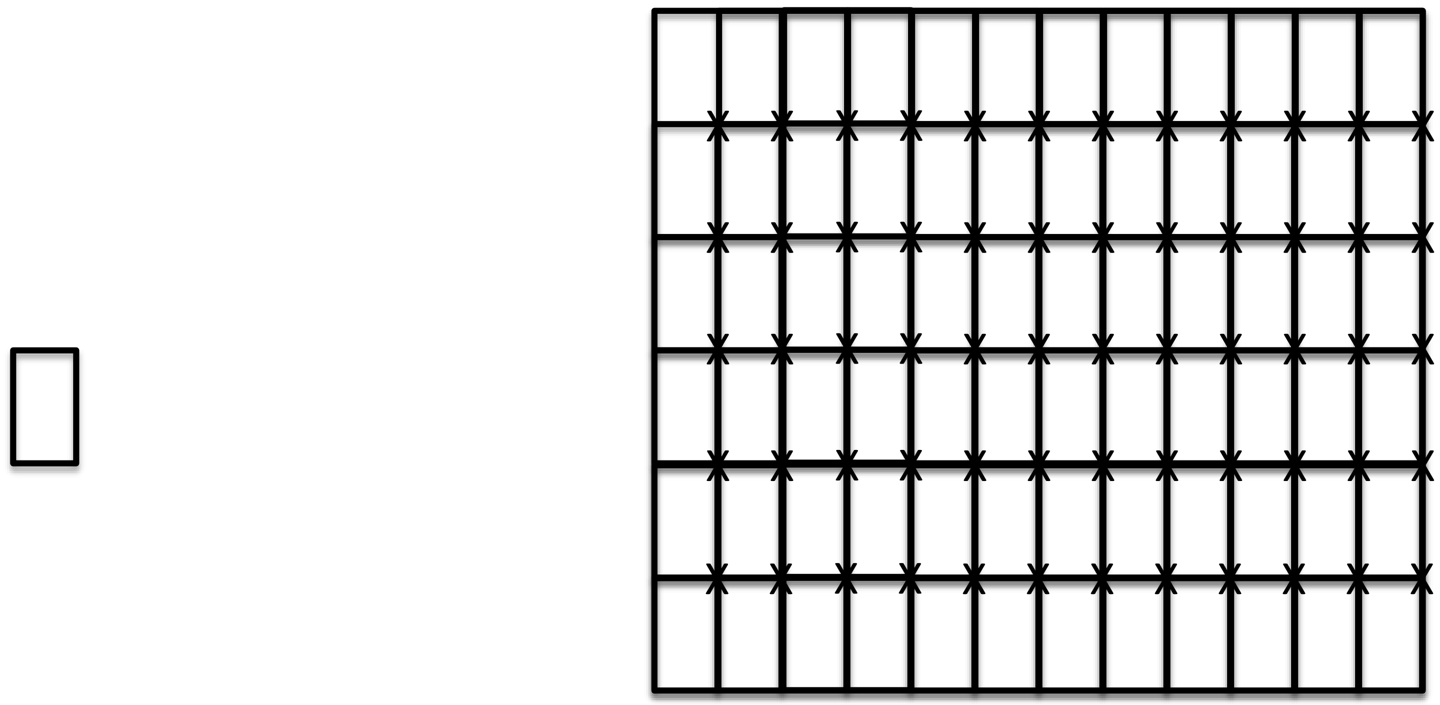
Why????

- Were we too busy drinking rum and chasing wenches?
- A more fundamental problem?

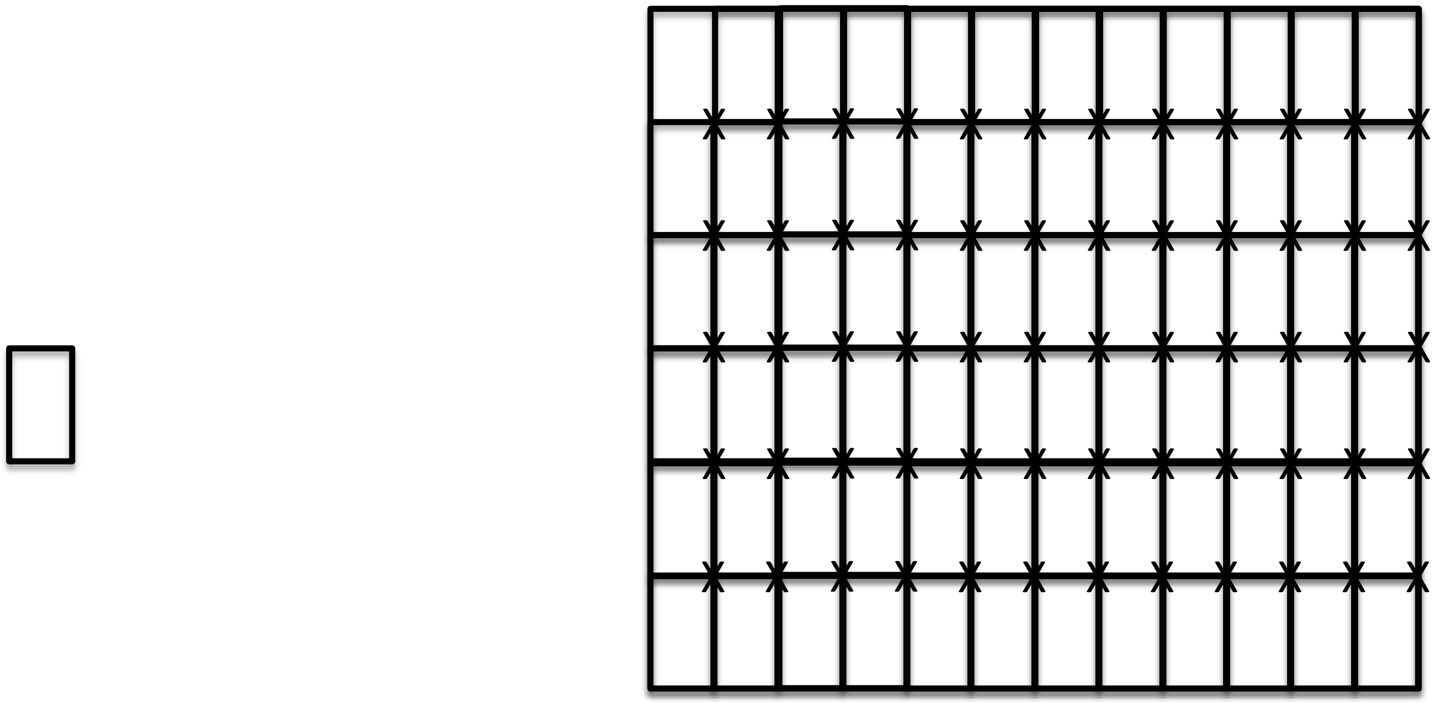
Mathematics to the rescue

An Optimal Strategy

An Optimal Strategy



An Optimal Strategy



Random vs. Optimal

- Random F-measure
  - area of treasure is *a*
  - area of island is *A*
  - F-measure for random is *A/a*
- Optimal (and yes it is optimal)
  - A/a test cases
  - On average, hit treasure half way through
  - F-measure is *A/2a*
- Captain Aaaart's strategy not far off optimal!

In case it's not obvious

- Island == input domain of software
- treasure chest = "failure region"
- Result still holds if multiple failure regions, n dimensions etc.
- Also holds if input domain modeled as discrete rather than continuous.

Upshot…

- If we're going to improve testing we need to change assumptions!

What is the ultimate goal anyway?

- Not digging for buried treasure!
- Multiple faults within input domain.
- Lead to multiple failure regions.
- Ultimate goal (Littlewood et al) – improve reliability as much as possible after faults detected in testing are fixed.
- Fiendishly hard to model ☹

Improving failure detection

- Incorporate guess where failures are most likely.
- Add some clues to the treasure map…

Failure-proportional sampling

- Discrete (and large)input domain, k inputs i_1, i_2,…i_k
- Prior probabilities for failure p_1, p_2…p_k
- Select randomly with replacement.
- Assign selection probability *s_i*= failure probability *p_i*
- Sounds like a good idea, right?

Optimal strategy

- Turns out to be no improvement on uniform random selection.
- Optimum strategy = $s_i = \sqrt{p_i}$
- Strategy came from Press(2009). Paper was about looking for terrorists.

Combining locality and probability

- Locality on its own -> 50% improvement
- Probability on its own -> not so useful either
  - Leads to repeatedly hitting high-probability areas.
- Need to combine them.
- Essentially, trying to have a formal mathematical model of debug testing
- But…modelling this is *really* hard.

The brute force model

i1	i2	i3	P
F	F	F	P1
F	F	T	P2
F	T	F	P3
F	T	T	P4
T	F	F	P5
T	F	T	P6
T	T	F	P7
T	T	T	P8

The brute force model

- Represents our prior beliefs about failure behaviour
- Can calculate our current beliefs about program reliability.
- In practice, table is intractably huge (2^input domain, where input domain is already huge)
- Not obvious what we'd do w/information to deliver reliability improvements.
- Despite size, doesn't represent everything we'd like to model ☹

Mistakes, failures and faults

- Mistakes (brain fart) -> fault (code fart) -> failure (output fart)
- To improve delivered reliability, fix the faults which cause the most failures.
- Need to incorporate in the model?
  - But model is already intractable!

So...I'm kinda lost