Mining Coverage Data for Test Set Coverage Efficiency

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Outline

• Coverage Efficiency
  • Coverage in Time
  • First Time Per Test Coverage
  • Hard To Hit Coverage

• Coverage Distribution
  • Scenarios to Waves
  • Wave Windows of Probability

• Controlling the Test Load

• Results & Conclusion

• Acknowledgments / References
Coverage Efficiency

- 12000 scenario files
- Millions of tests
- Coverage
  - All Events 150k
  - Hard-to-Hit 73k
  - Never-Hit events 15k
  - Coverage driven verification
  - Coverage driven test case generation
  - Graph based test case generation

Automatic or manual targeting
Coverage Efficiency

• Coverage
  – Never-Hit
  – Hard-to-Hit
  – Often-Hit $\Rightarrow$ redundancy

• Efficiency
  – Achieve coverage goal less resources
  – Reduce redundancy

• Observe
  – Summarization, model identification, probability

• Control
  – Control the test case generation

used to drive the verification process
Coverage in Time

- Same scenario:
  - Semaphores
  - Locking mechanism

- Same load
  - Nb. of instr.
  - Nb. of cycles
First Time Per Test Coverage

Test A

Test B

Same Scenario

DSI_EAO

All Events

FTPT
FTPT Gamma Distribution

A LARX_STCX Test
Mixture of Coverage Waves

- Expectation Minimization (EM) algorithm to identify the mixture of Gaussians
- Waves show the exercising of a new area in the design
- We do not target coverage, target coverage waves
Different Scenarios

Four tests, two different scenarios

(DSI_EAO 456 and 163 and ATOMIC 58 and 20)
Scenarios to Generate Certain Waves

Particular wave(s) targeted by each scenario =>

Focus on the Hard-To-Hit waves for each scenario
HTH Coverage Wave Windows

For each scenario
- Identify which hard-to-hit wave it targets
- Identify the conditions under which it succeeds to achieve it.

Cycle window likely to see a given wave.
Overall Probability
=>
Identifies the Hard-to-Hit cycle windows

• Probability mass function for event e
  \[
  \Pr(\{\text{event } e \text{ hit; cycle } = c\})
  \]
  Probability test to hit e
  \[
  P(e) = \frac{N \text{ tests_hit}_e}{N \text{ tests}}
  \]
HTH-FTPT
Load Dependency
Experimental Test Size to HTH Coverage

40 tests; TM

Coverage

Test Load Increases (Simulation Cycles)

Original Size

40000 cycles+

Overall Coverage

Hard-To-Hit Coverage
Summary

• Coverage Efficiency

• Observe
  – Coverage in Time
  – FTPT Coverage in Time – HTH
  – Coverage waves Mixture – Model Fitting
  – Probability distributions

• Control
  – Test case number of instructions

• Industry results
Results

• Decreased hard-to-hit by 12%
  – 73,000 to 64,000
• Never-hit before events decreased by 13%
  – 15,000 to 13,000
  – saving 18 Person/Months.
• Less redundancy on easy-to-hit coverage.
• Shifted manual work to the automatic process
• Decreased time to achieve targeted coverage => enabled finding bugs earlier.
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References

• Bruce, W., Gross, C. J. & Roesner, W., 2005. *Comprehensive functional verification the complete industry cycle.* Amsterdam: Elsevier/Morgan Kaufmann.