Test Prioritization

17-654/17-765
Analysis of Software Artifacts
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Test Prioritization: Motivation

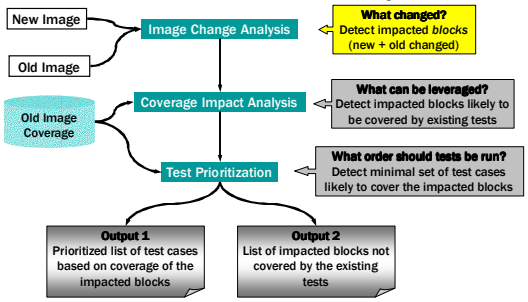
- Goal: find and eliminate newly introduced defects
- Regression Testing for Windows
  - Many tests
  - Many platform configurations to run them on
  - Full tests take weeks to run
- Test Prioritization
  - Want to run tests likely to fail first
  - Day 1 after internal release, not day 21!
- Test Selection
  - What tests should I run before checking in code?
  - What tests should be run before releasing a critical fix?
  - Special case of prioritization

Observation: New defects are introduced from changed code

Challenges in Test Prioritization

- Detecting change and affected parts of the program
- Scalability to handle complex systems
  - Tens of millions of tests
  - Thousands of developers and testers
  - Tens of millions lines of source code
  - Acceptable response times
- Integrating seamlessly into development process

Scout: Test Prioritization System



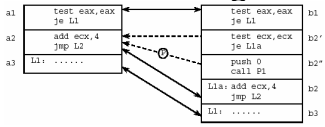
BMAT – Binary Matching

- Goal: detect corresponding blocks in old and new versions of a program
  - [Wang, Pierce, and McFarling JILP 2000]
- Matches basic blocks in binary code
  - + don't need source code
  - - must ignore changes in address space
- Algorithm considers similarities in code and in its uses

BMAT – Matching Procedures

- Match procedures if names match
  - Qualified by package, scope, etc.
  - If ambiguous, extend to include argument types
- Check for similar names
  - Verify match if blocks are similar (see below)
- Look for function bodies hashing the same
- Pairwise compare blocks otherwise
- If no match, conclude function is new

BMAT – Matching Blocks

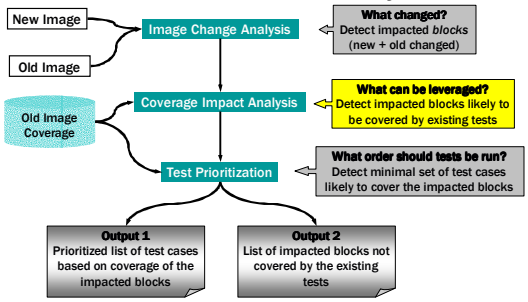


- Match blocks based on hash of contents
  - Look for exact match first, then apply fuzzy hashing algorithm
    - Fuzzy algorithms ignore information that is likely to change due to innocuous changes: offsets, registers, block addrs, opcodes
- Control-flow match
  - Build CFG, look for node pairs with the same connectivity
  - May match many new blocks to one old block
  - Partial match: new block not always executed (e.g. b2'')

Detecting Impacted Blocks

- Old blocks
  - Identical (modulo address changes)
- Impacted blocks
  - Old modified blocks
  - New blocks

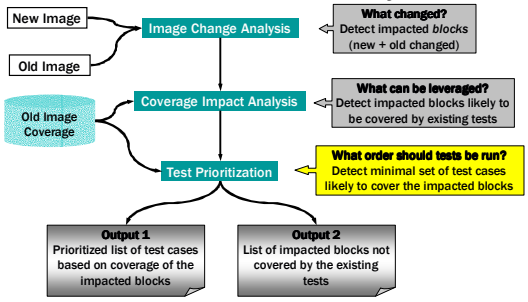
Scout: Test Prioritization System



Computing Coverage

- Computed for each test T
- Old block b
  - Covered if T covered b in old binary
- New block
  - Covered if at least one predecessor and successor were covered in old binary
  - Heuristic: predict edges taken
  - Heuristic: don't check predecessors for indirect call targets

Scout: Test Prioritization System



Prioritization Algorithm

Input:
TestList: set of tests
Coverage (t) : set of blocks covered by test t
ImpactedBlkSet: set of new and old modified blocks

Output: a set of sequences Seq

Algorithm:
```
while (any t in TestList covers any block in ImpactedBlkSet )
{
  CurrBlkSet = ImpactedBlkSet
  Start a new sequence Seq
  while (any t in TestList covers any block in CurrBlkSet )
  {
    for each t in TestList compute
    {
        Weight(t) = count[CurrBlkSet ∩ Coverage(t)]
    }
    Select test t in TestList with maximum weight
    Add t to current sequence Seq
    Remove t from TestList
    CurrBlkSet = CurrBlkSet – Coverage (p)
  }
}
Put all remaining tests in TestList in a new sequence Seq
```

Test	Blocks
t1	b2,b7
t2	b1,b2,b3,b8
t3	b7
t4	b6
t5	b1,b2,b5
t6	b4,b5

Impacted: b1,b2,b4,b7,b8

Seq1:
Seq2:
Seq3:

Echelon Performance: ProductX.EXE

Image Info

	Build 2411.1	Build 2529.0
Date	12/11/2000	01/29/2001
Functions	31,020	31,026
Blocks	668,068	668,274
File size	8,880,128	8,880,128
PDB size	22,602,752	22,651,904
Number of Traces	3,128	3,128

Results

Impacted Blocks	378 (220 New, 158 OC)
Likely Covered by existing tests (LC)	176 Blocks
Traces needed to cover LC (Set 1)	16 Traces
Number of sets in prioritized list	1,225

1.8 million lines of source code

Scout took about 210 seconds

Test Sequence Characteristics

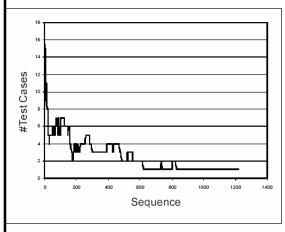


Figure 3. Number of tests in each sequence

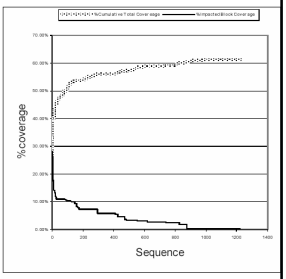


Figure 5. Cumulative coverage and impacted coverage

Prediction Errors

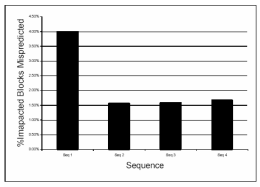


Figure 6. Predicted blocks not covered

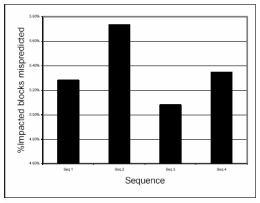


Figure 7. Blocks covered but not predicted

1-4% False Positives

4-5% False Negatives

Defect Detection

Program A

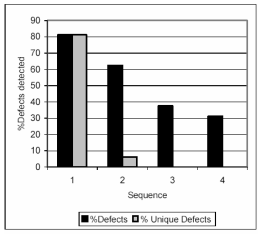


Figure 12. Defects detected in each sequence

Program B

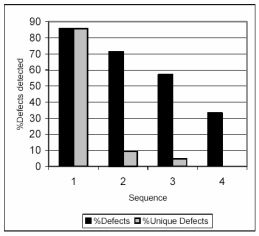


Figure 13. Defects detected in each sequence

Summary: Test Prioritization

- Effectively being used in MS Windows, SQL, and Exchange development process
  - Quickly identifies tests most likely to detect errors
- Scales to production environments - millions of tests and thousands of binaries
- Combination of approximations and static analysis to eliminate manual methods
- Collect information about development process