National Aeronautics and Space Administration

Directed Incremental Symbolic Execution

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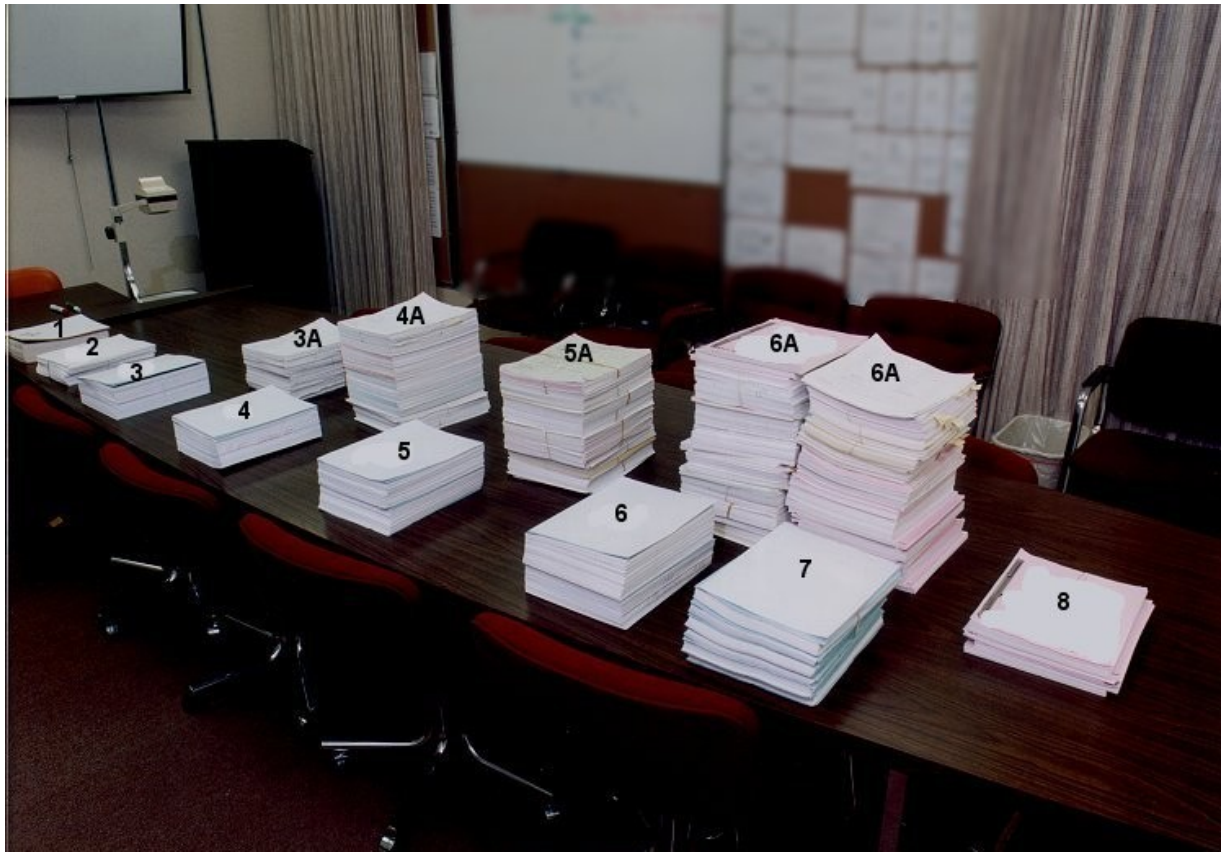
2011 Annual Technical Meeting
May 10–12, 2011
St. Louis, MO

Motivation

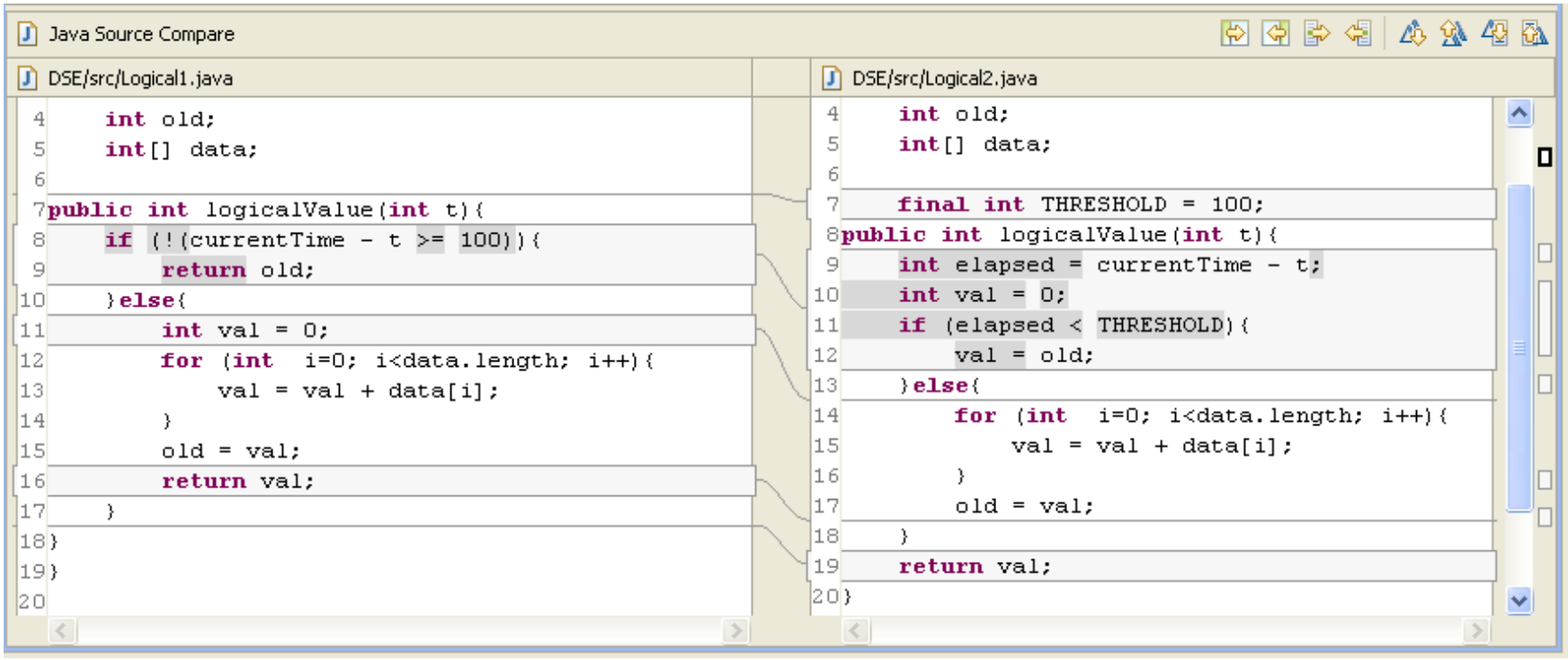
"Nothing endures but change."

Heraclitus, Greek
Philosopher
(c. 535 BC – 475 BC)

Motivation



Motivation




```
4     int old;
5     int[] data;
6
7  public int logicalValue(int t){
8     if (!(currentTime - t >= 100)){
9         return old;
10    }else{
11        int val = 0;
12        for (int  i=0; i<data.length; i++){
13            val = val + data[i];
14        }
15        old = val;
16        return val;
17    }
18 }
19 }
20
```

```
4     int old;
5     int[] data;
6
7     final int THRESHOLD = 100;
8  public int logicalValue(int t){
9     int elapsed = currentTime - t;
10    int val = 0;
11    if (elapsed < THRESHOLD){
12        val = old;
13    }else{
14        for (int  i=0; i<data.length; i++){
15            val = val + data[i];
16        }
17        old = val;
18    }
19    return val;
20 }
```

DiSE

- Regression analysis technique focused on version differences
- Leverages efficiencies of syntactic analysis results to guide semantic analysis
- Identifies and characterizes the *effects* of program changes

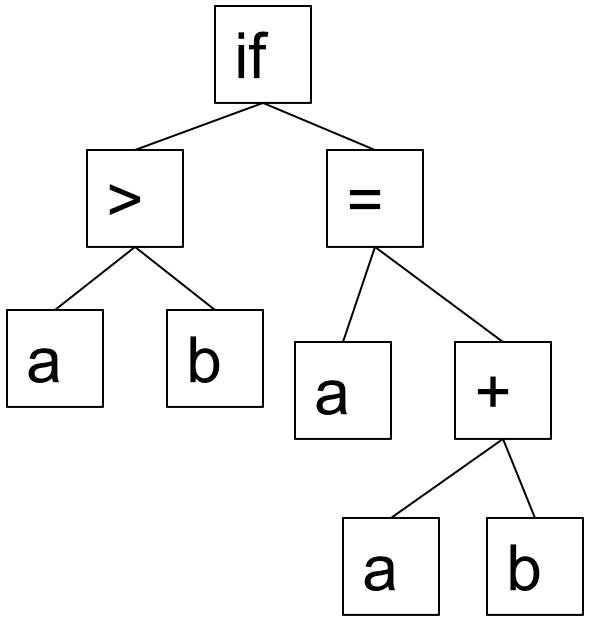
Overview of Presentation

- Motivation
- Background
- DiSE Methodology
- Evaluation
- Conclusions and Future Work

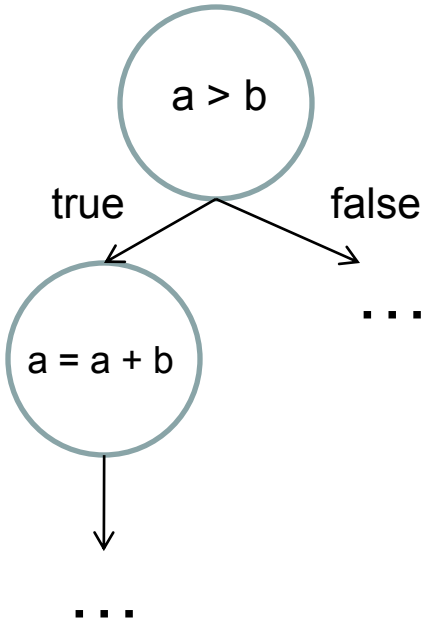
Background

- Abstract Syntax Tree

```
if (a > b)
  a = a + b;
```



- Control Flow Graph

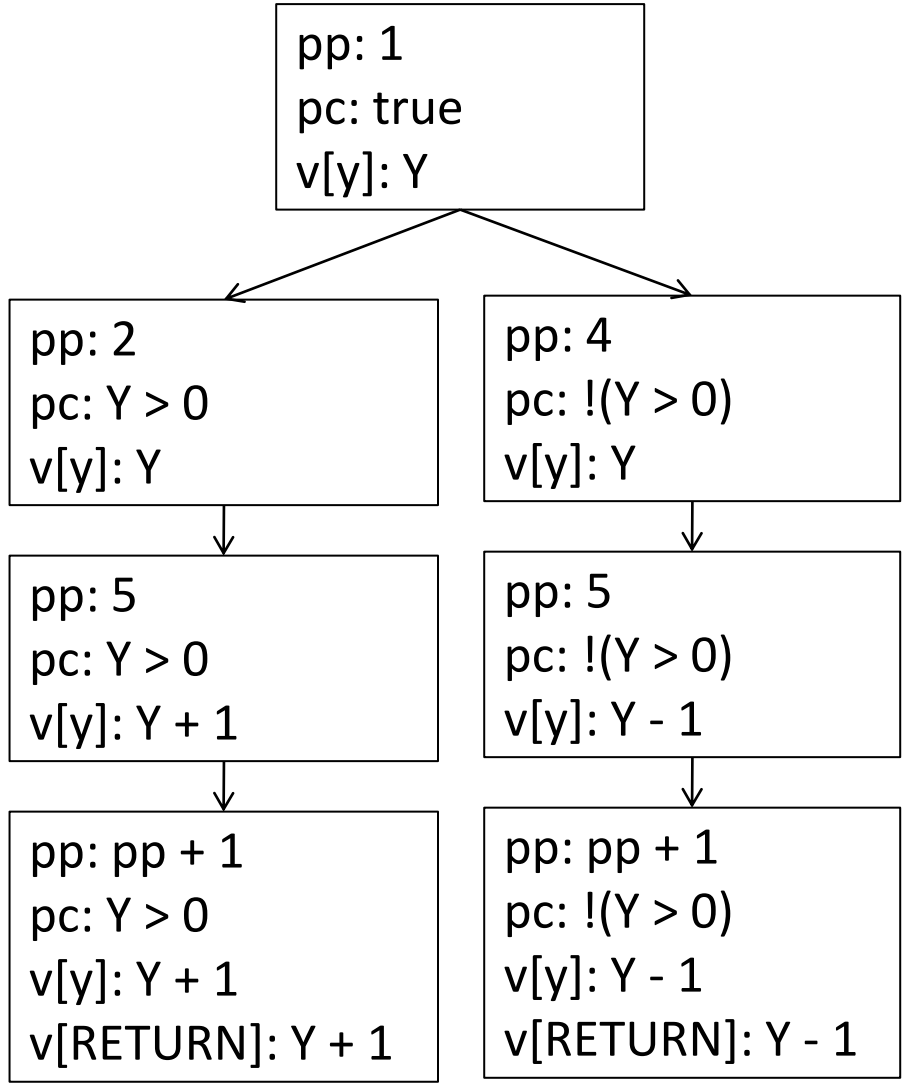


Background

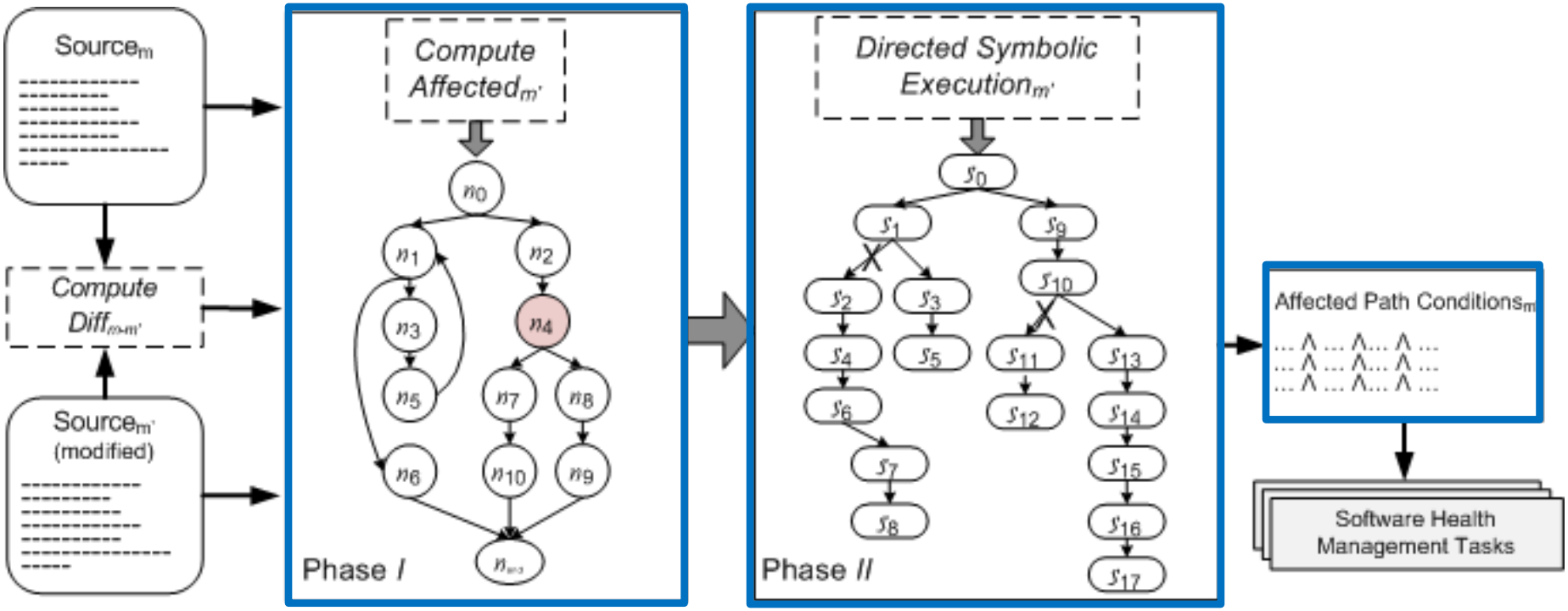
- Symbolic Execution

```
int m(int y){
1:  if (y>0)
2:    y++;
3:  else
4:    y--;
5:  return y;
}
```

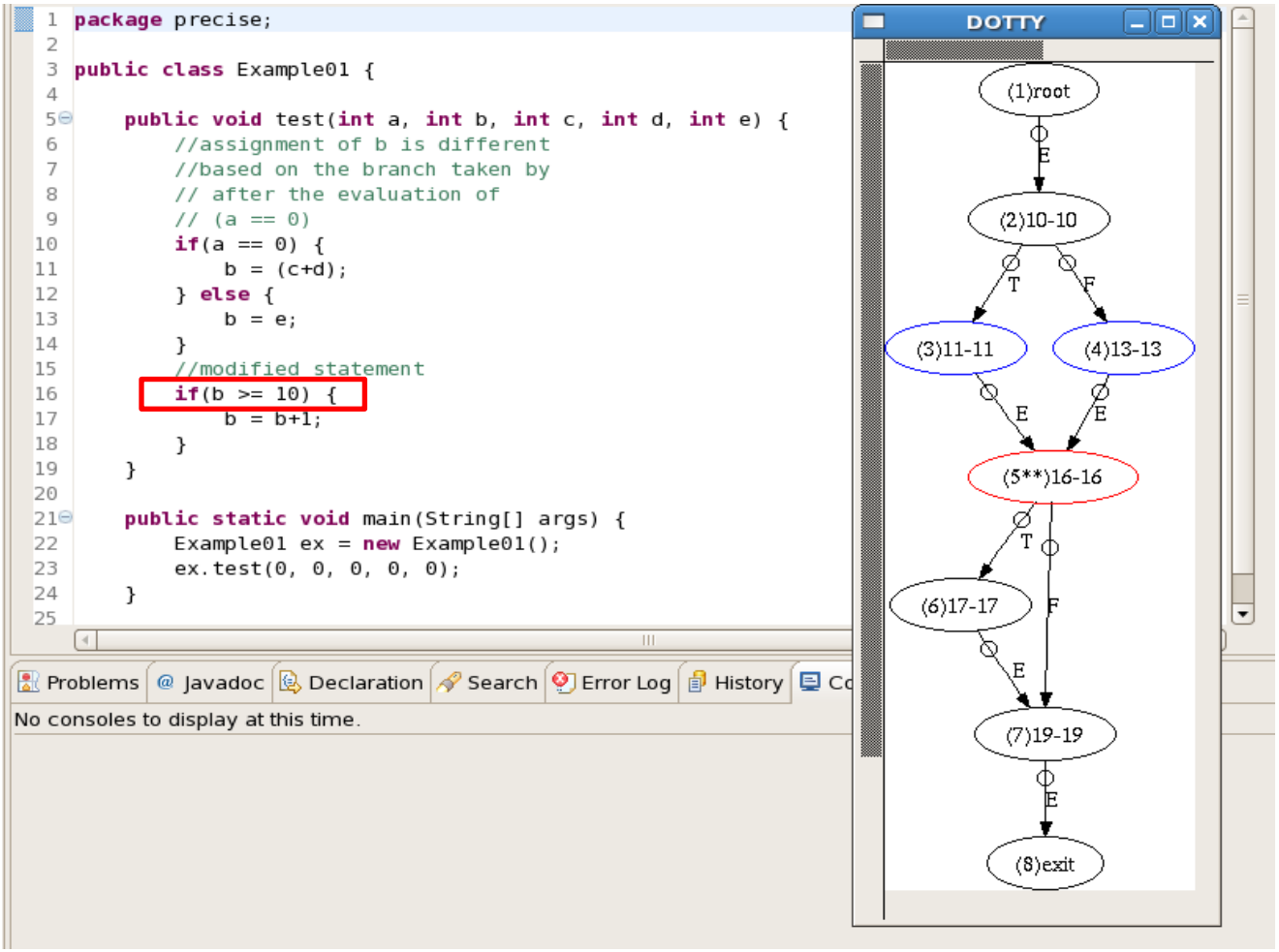
m_{sum}=
{((Y>0), RETURN=Y+1),
!(Y>0), RETURN=Y-1)}



DiSE Methodology

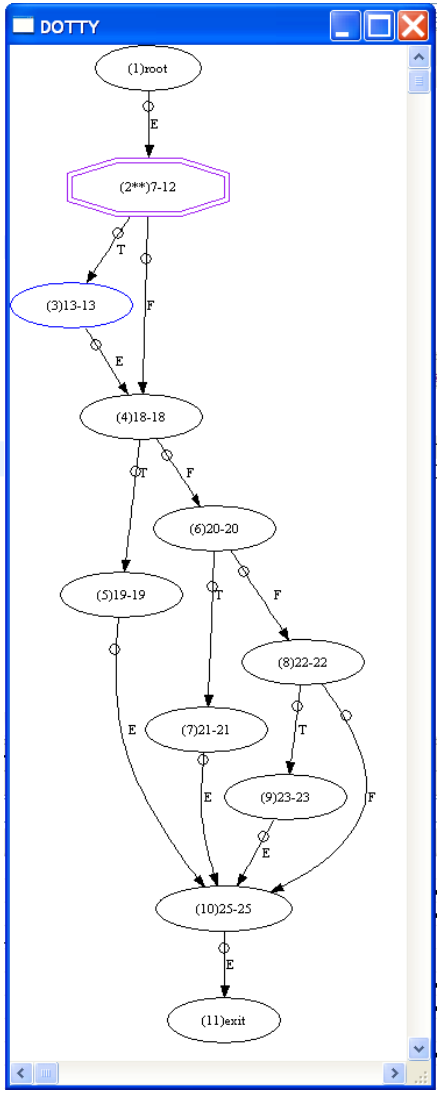


DiSE Methodology



DiSE Methodology

```
1  package precise;
2
3  public class Example05_mod{
4
5      public void test (int a, int b, int c, int d, int x) {
6          //modified statement
7          b = b - x;
8          int e = (a + b);
9          int f = (e - x);
10         // conditional branch statement
11         // affected by the change
12         if((e + f) == (c+d)) {
13             e = f;
14         }
15         // no path conditions should be generated
16         // during this set of conditional branch
17         // statements
18         if (c == d) {
19             c = d+1;
20         } else if (c < d) {
21             c = d+2;
22         } else if (c > d ) {
23             c = d+3;
24         }
25     }
26
```



2 affected path conditions

Evaluation

- Implementation
  - Custom application to compare ASTs
  - Custom data and control dependence analysis
  - Extension to NASA Ames Java PathFinder toolset
    - Leverages Symbolic PathFinder extension

Evaluation

- Artifacts
  - Three control applications written in Java
    - Wheel Brake System (WBS)
    - On-board Abort Executive (OAE)
    - Altitude Switch (ASW)
  - Manually created version history

Evaluation

- Research Questions

  RQ1 (Cost): How does the cost of applying DiSE compare with full symbolic execution of the changed method?

  RQ2 (Efficiency): How does the number of path conditions generated by DiSE compare with the number of path conditions generated by full symbolic execution?

Evaluation

- Observations
  - DiSE incurs little overhead for all three examples
  - For most version differences, DiSE computed many fewer Path Conditions
  - Factors affecting reductions
    - Number of changes
    - Location and nature of the change
    - Program structure

Evaluation

- Limitations
  - DiSE performs an intra-procedural dependence analysis
    - Does not consider the effects of the return value of a method
    - May miss affected path conditions that affect the global state

Conclusions and Future Work

- DiSE combines *efficiencies* of lightweight static analysis techniques with *precision* of symbolic execution to explore and characterize the parts of a program impacted by changes
  - General technique that does not require analysis results to be carried forward
  - Evaluation demonstrates effectiveness of DiSE relative to full symbolic execution

Conclusions and Future Work

- Extend DiSE
  - Inter-procedural analysis
  - Leverage information from previous runs
- Evaluate on wider range of programs
- Explore other applications of DiSE results

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