Automated Adaptive Bug Isolation using Dyninst

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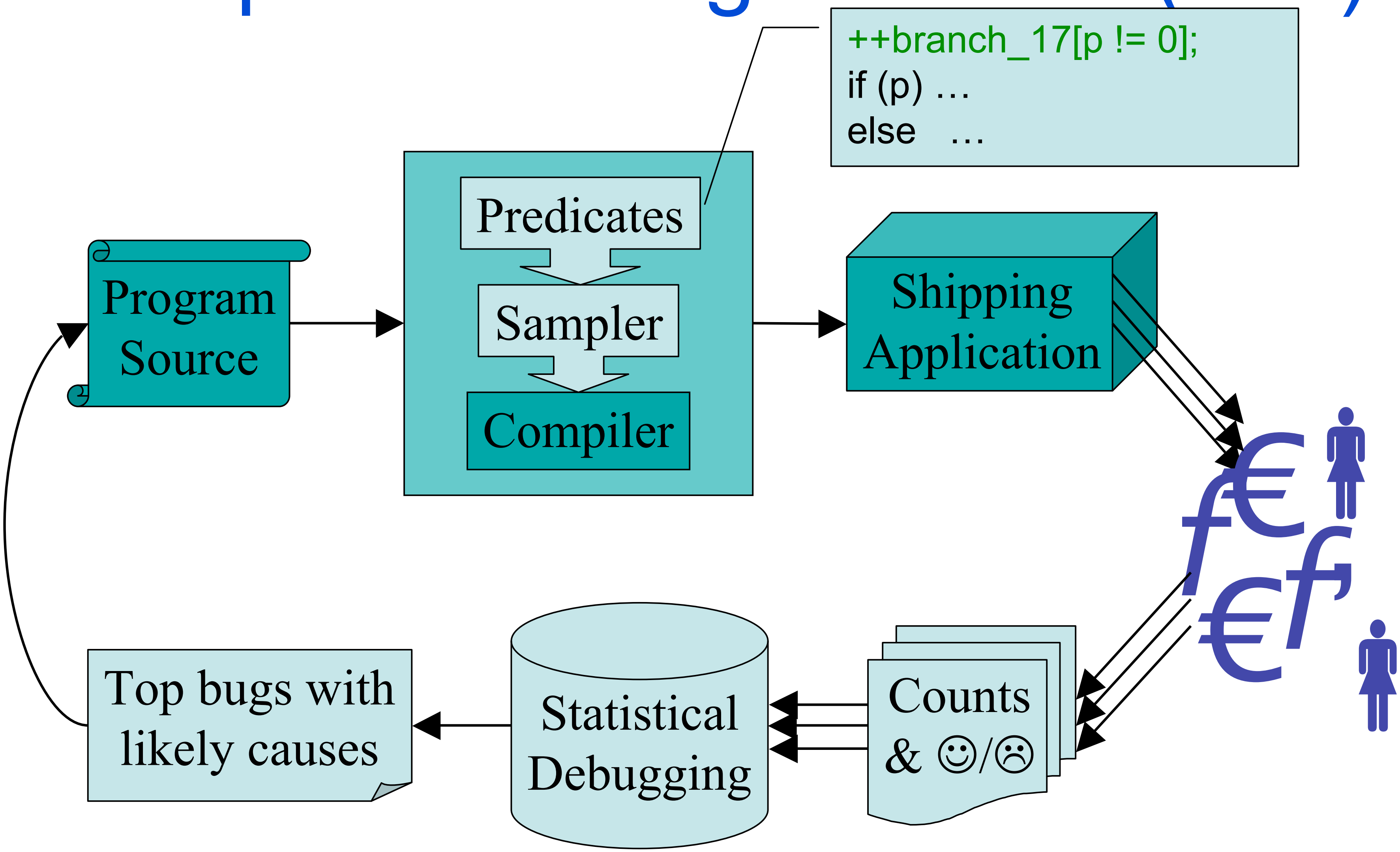
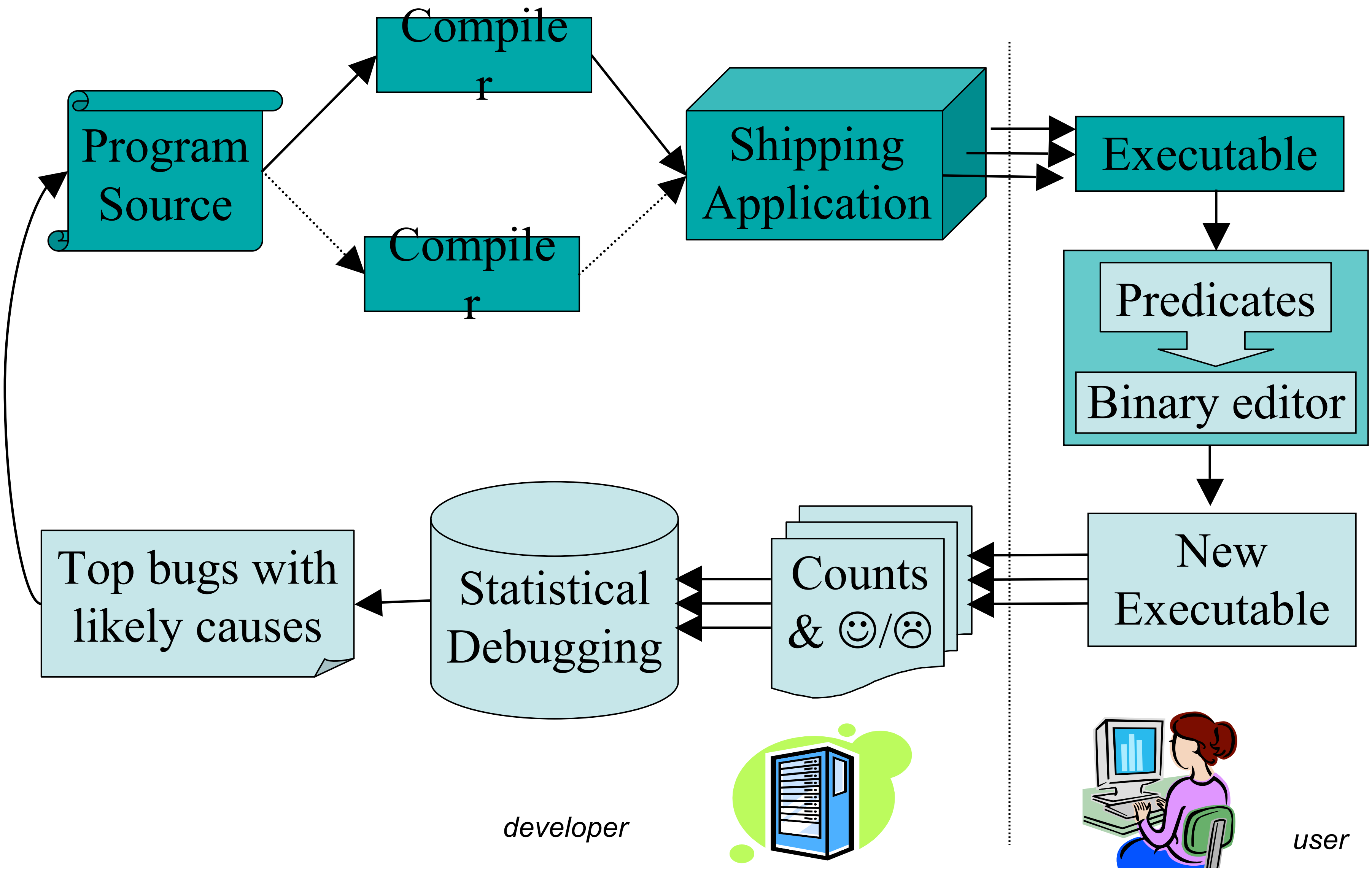
Cooperative Bug Isolation (CBI)



Issues

- Problem with static instrumentation
  - Predicates are fixed for entire lifetime
  - Three problems
    1. Worst case assumption
    2. Cannot stop counting predicates
       - After collecting enough data
    3. Cannot add predicates we missed
- Current infrastructure supports only C programs

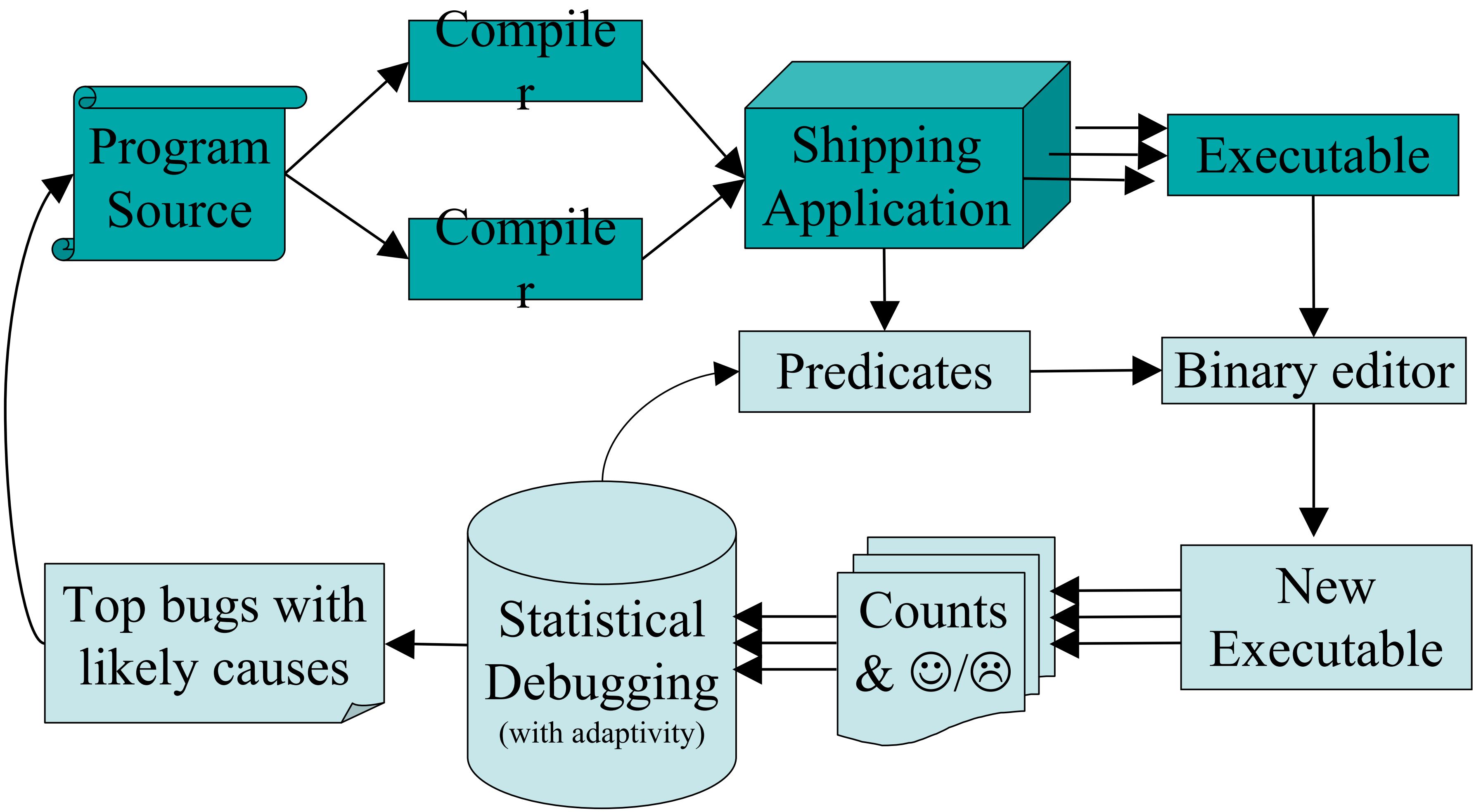
CBI for Binaries



Adaptive Bug Isolation

- Strategy:
  - Adaptively add/remove predicates
    - Based on feedback reports
- Retain existing statistical analysis
  - Goal is to guide CBI to its best bug predictor
    - Reduce the number of predicates instrumented

Adaptive Bug Isolation (contd.)

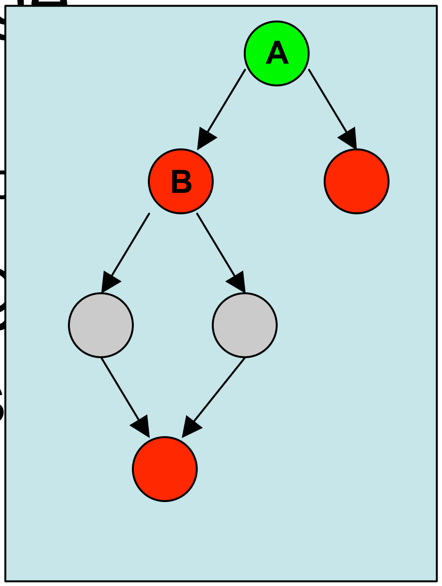


Dyninst Instrumentor - Features

- Counters in shared segment
- Removes snippets
  - After they execute once
- Call graph, CFG, dominator graphs
- Snippets are feather weight
  - Don’t save/restore FPRs
- More…
  - Better overheads
  - Expose data dependencies

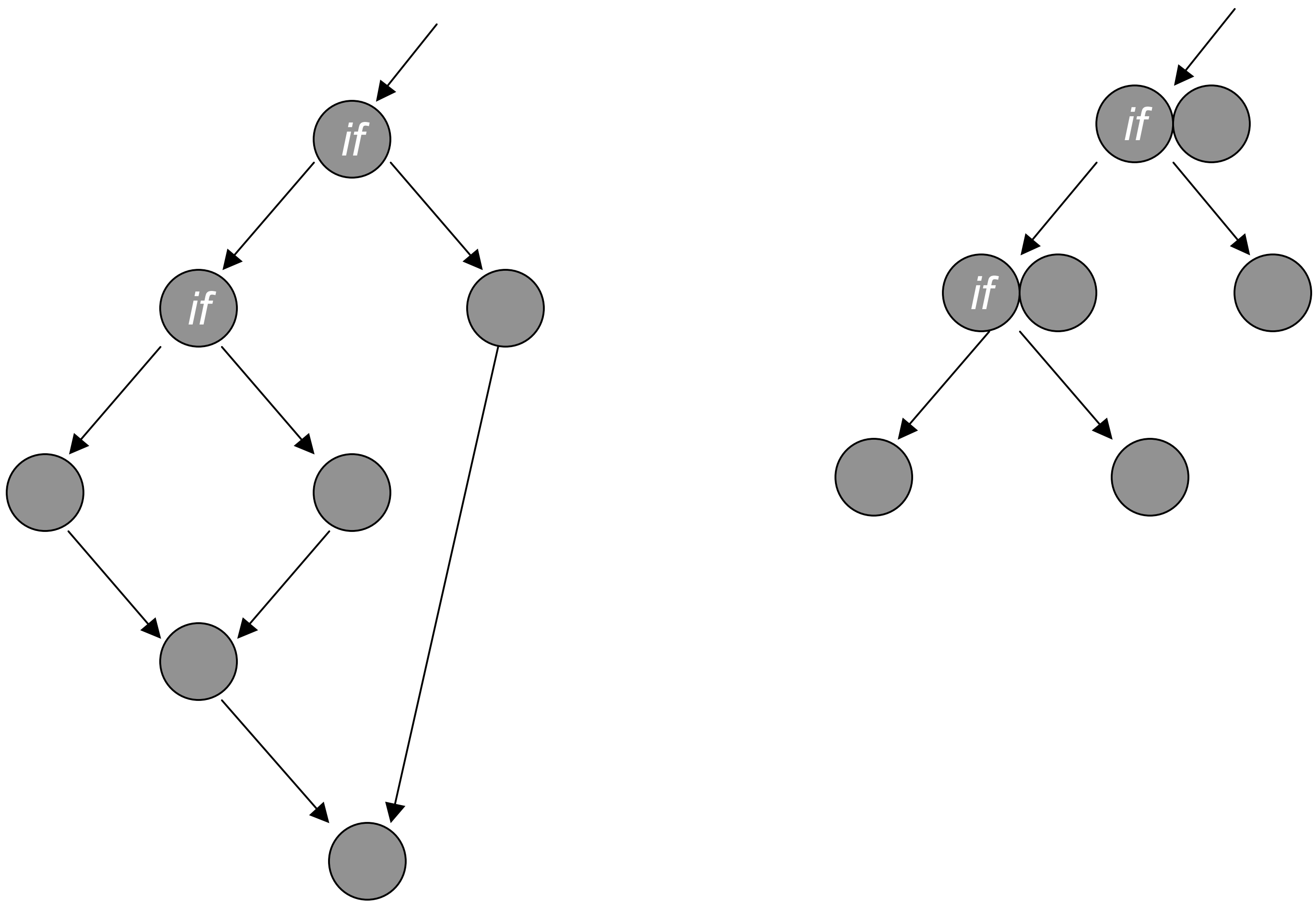
Technique

- Control Dependence Graph (CDG)
- Algorithm:
  - For each *suspect* branch edge:
    - Enable all predicates in
      - basic blocks control dependent o
- How to identify suspect edg
  - Pessimistic - all edges are s



Simple strategy: BFS

- All branch predicates are suspicious



Can we do better?

- Assign scores to each predicate
- Edges with high scores are suspect
  - Many options
    - Top 10
    - Top 10%
    - Score > *threshold*
  - For our experiments, only the topmost predicate
  - Other predicates: may be revisited in future
- Key property: If no bug is found, no predicate is left unexplored

Scores – heuristics 1,2,3

- Many possibilities. We evaluate five
- For a branch predicate p,
  - F (p) = no. of failed runs in which p was true
  - S (p) = no. of successful runs in which p was true

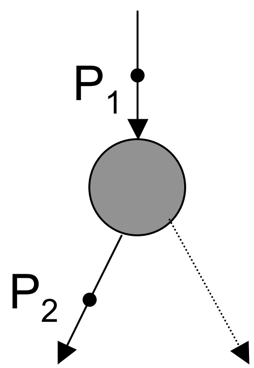
1. Failure count: F (p)
2. Failure probability: F (p) / (F (p) + S (p))
3. T-Test

	Succ	Fail.
p true	30%	70%
p false	50%	50%

Pr (p being true affects program outcome in a statistically significant manner)

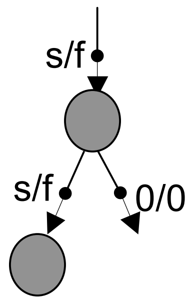
Scores - heuristic 4

4. *Importance* (p)
   - CBI's ranking heuristic [PLDI '05]
   - Harmonic mean of two values
   - For a branch predicate 'p':
     - Sensitivity
       - log (F (p)) / log (total failures observed)
     - Increase
       - Pr (Failure) at P_2 – Pr (Failure) at P_1



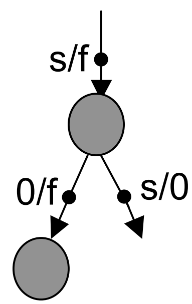
Scores - heuristic 5

5. Maximum possible *Importance* score
   - Problem: sometimes, *Importance* (p) mirrors *p*’s properties and says nothing about the branch’s targets



Edge label a/b means
- Predicate was true in ‘*a’* successful runs
- Predicate was true in *‘b’* failed runs

   - score (p) = Maximum possible Importance score in p’s targets



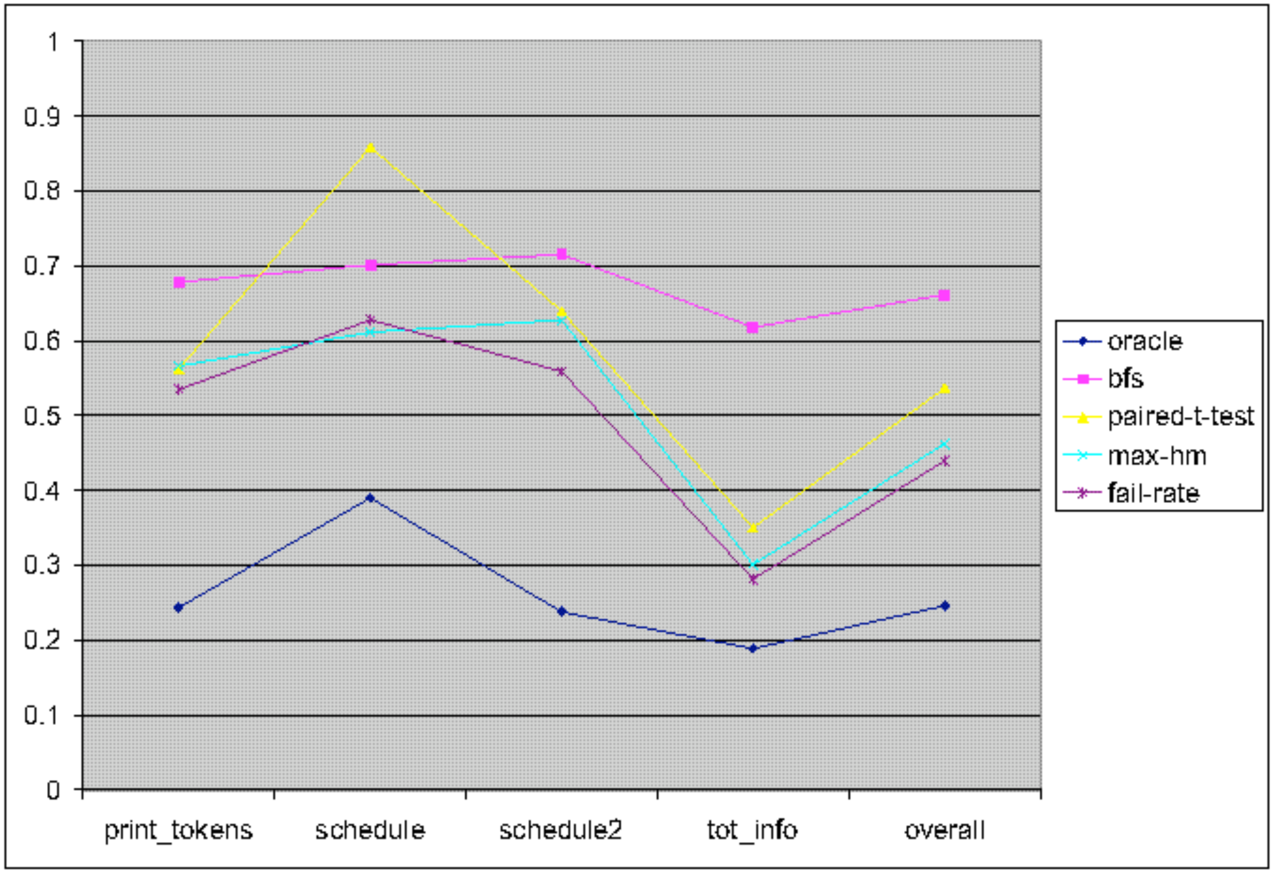
Optimal heuristic

- Oracle
  - points in the direction of the target (the top bug predictor)
  - Used for evaluation of the results
  - Shortest path in CDG

Evaluation

- Binary Instrumentor: using DynInst
- Heuristics:
  - 5 global ranking heuristics
  - simplest approach: BFS
  - optimal approach: Oracle
- Bug benchmarks
  - siemens test suite
- Goal: identify the best predicate efficiently
  - Best predicate: as per the PLDI ’05 algo.
  - efficiency: no. of predicates examined

Evaluation (cont.)



Conclusion

- Use binary instrumentation to
  - Skip bug free regions
    - ➔more data from interesting sites
- Fairly general
  - Can be applied to any CBI-like tool
- Backward search – in progress

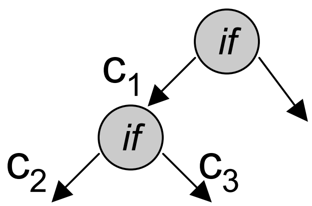
Questions?

Binary Instrumentor

- Using DynInst
- Large slowdowns

25 times for go (SPEC)

- Reduce no. of branch predicates



If program crashes between p_1 and p_2

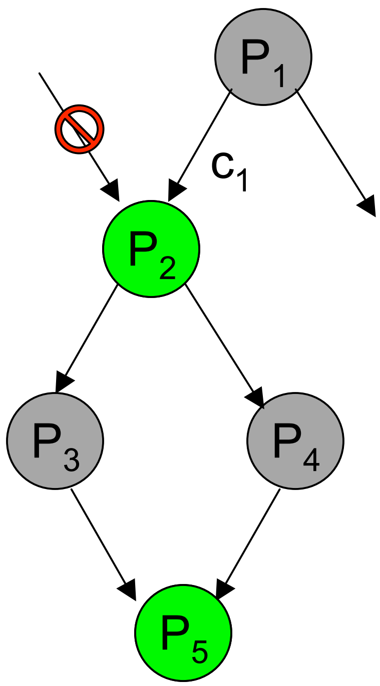
$$c_1 = c_2 + c_3 + 1$$

else

$$c_1 = c_2 + c_3$$

- Gathering *true*/*false* values instead of counts
  1. No increment. Just store 1 (*true)*
  2. Self-removing instrumentation
     - Removes itself after executing
     - Applies only to dynamic instrumentation
- Better performance: 2-3 times slowdown for go
  - But not enough

Branch predicate inference



- c_1 can inferred if
  - P_1 *dominates* P_2
  - P_2 or P_5 have an instrumentation site

    (in general, any block *equivalent* to P_2)

Can we do better?

- Choose one branch over the other

	Succ	Fail.
then path	30%	70%
else path	50%	50%

Program fails more often in the *then* path

Pr (there is a significant difference in the two directions)

use *T-Test* (paired)

  – Strategy:
    - if Pr (statistically significant difference) > 95%:
      – Only *then* path is interesting
    - else both *then* and *else* paths are interesting

Simple strategy: BFS

- All branch predicates are suspicious