BugMD: Automatic Mismatch Diagnosis for Bug Triaging

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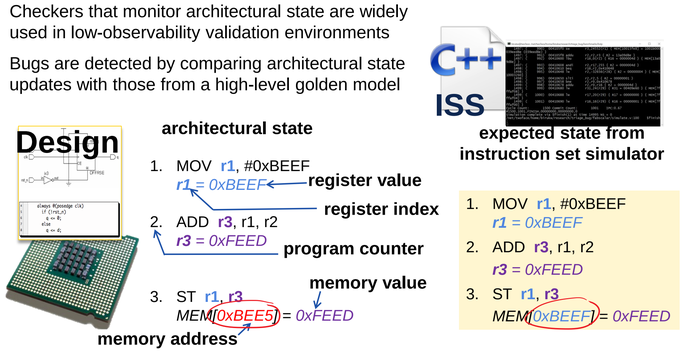
1. Motivation

Checkers that monitor architectural state are widely used in low-observability validation environments

Bugs are detected by comparing architectural state updates with those from a high-level golden model



***0xBEE5 ≠ 0xBEEF* : Mismatch!**

2. Limitations

- Diagnosis is difficult
  - Several thousands of cycles between bug occurrence and manifestation
  - Low-observability, limited information
- Simulation stops typically after first mismatch
  - Patterns may emerge if simulation continues to collect more mismatches

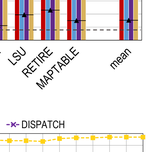
3. (0x0C) ST r1, r3
   MEM[0xBEE5] = 0xFEED
4. (0x10) MOV r2, #4
   r2 = 0x0004
5. (0x14) ADD r4, r3, #1
   r4 = 0xFEE4
6. (0x18) BR +0x10
   PC = 0x0020

Instr. count	mismatch type	instr. type	design value	ISS value
3	MEM ADDR	MEM	0xBEE5	0xBEEF
5	REG VALUE	ALU	0xFEE4	0xFEEE
6	PC VALUE	CONTROL	0x0020	0x0028

What happens when design execution diverges?

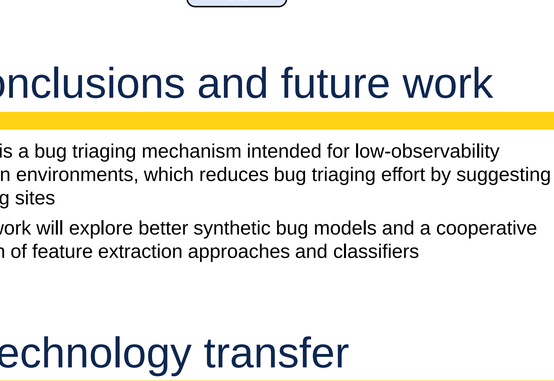
How do we automatically identify patterns?

How do we get enough data to learn multiple patterns?

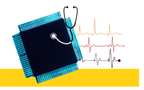


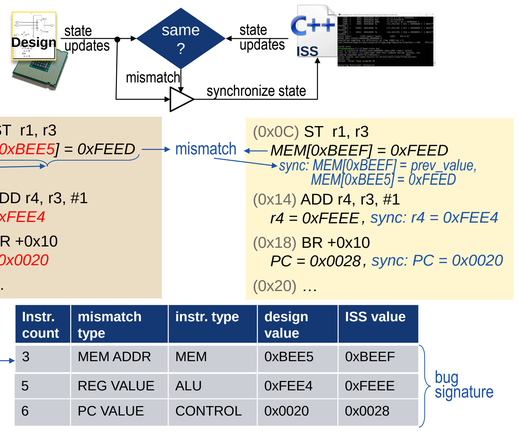
3. BugMD: key contributions

- Collects multiple, independent symptoms
  - Runs simulation past first mismatch
  - Avoids divergence by synchronizing ISS with design
- Learns patterns, without detailed µArch. knowledge
  - Generates feature vectors from multiple mismatches
  - Trains a machine-learning classifier
- Generates synthetic training data
  - Automatically injects thousands of bugs into the design



4. Symptom collection





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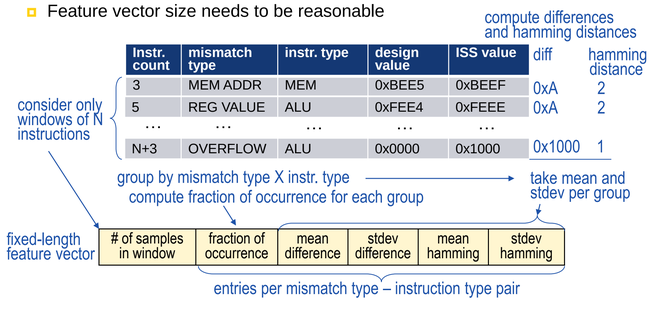
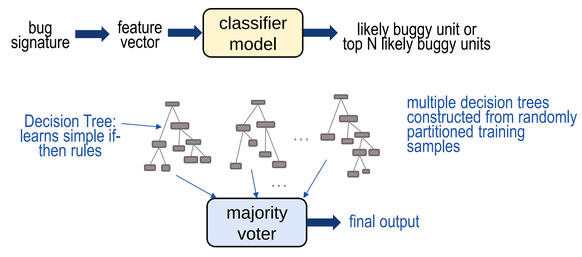
5. Learning patterns: features

- Unprocessed bug signatures are not amenable to machine learning
  - ML algorithms take fixed-size, real valued feature vectors
  - Bug signatures have arbitrary sizes, from 0 to millions of entries per simulation
  - Symptoms need to be converted to meaningful, real-valued features
  - Feature vector size needs to be reasonable



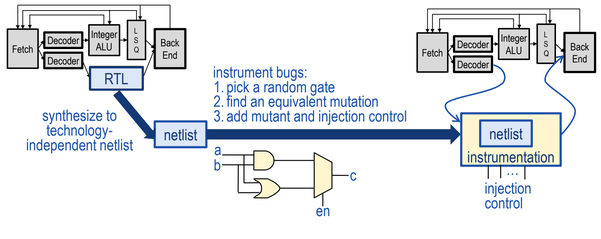
6. Learning patterns: classifier

- Investigated several machine-learning algorithms
  - Classic machine-learning classifiers (SVM, naïve bayes, etc.)
  - Multi-layer perceptron neural network
  - Convolutional neural network
- ***Random decision forest*** algorithm performed the best



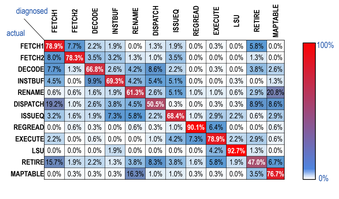
7. Injecting synthetic bugs

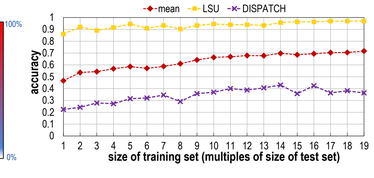
- Classifier model has to be trained on known bugs
  - Known buggy unit along with associated bug signature(s)
  - Large amount of training data required for learning
- We developed a synthetic bug model and injection framework
  - Random gate mutations to model bugs
  - Automatic bug instrumentation and flexible injection control during simulation



8. Results

- 4-wide, out-of-order FabScalar core, 12 design units
- 6 instruction types
- 34 mismatch types
- 10,000 instruction window, feature vectors of size 470
- 7080 synthetic bugs, over 40,000 bug signatures





9. Conclusions and future work

- BugMD is a bug triaging mechanism intended for low-observability validation environments, which reduces bug triaging effort by suggesting likely bug sites
- Future work will explore better synthetic bug models and a cooperative selection of feature extraction approaches and classifiers

10. Technology transfer

- Industry interactions
  - Dr. Daya S. Khudia was hired by Intel Corporation
- Publications/presentations
  - To appear in proceedings of ICCAD'16
  - Manuscript uploaded to SRC