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.

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. 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

- 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

5. Learning patterns: features

- Fixed-length feature vector
  - Fraction of occurrence for each group
  - Unusual mismatch pairs

6. Learning patterns: classifier

- Random decision forest algorithm performed the best
  - Multi-layer perceptron neural network
  - Convolutional neural network

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 FatScalar core; 12 design units
  - 6 instruction types
  - 34 mismatch types
  - 10,000 instruction window, feature vectors of size 470
  - 7,800 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