Introduction to
Advanced Combinatorial Testing System

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NIST and our collaborators

- NIST mission: advance technology through better measurements, standards, and test methods
- 3,000 staff, 4 Nobel laureates, 1000 guest researchers
- ACTS goals: advance technology to reduce testing cost, improve effectiveness, demonstrate applications
Combinatorial (t-way) Testing

- Generic testing methodology for any investigation that can be mapped into exercising system under test (SUT)
- for a suite of $N$ test cases formed from $k$ test factors having $v_1$, $v_2$, ..., $v_k$ discrete test settings
- possible number of test cases $v_1 \times v_2 \times \ldots \times v_k$
- combinatorial methods are used to determine a small $N$
- such that all $t$-way combination of test settings are tested for a chosen $t < k$; $t$ is strength
- with object of identifying a combination for which SUT may behave differently than expected
Investigation of actual faults

• In 1990s, Kuhn et al investigated actual failure reports
  – What kind of testing would have prevented failures?
  – Number of individual factors involved in faults

• Most involved 1 or 2, progressively fewer 3, 4 or more
Pairwise to combinatorial testing

- In 2005 pair-wise testing using orthogonal array was new
  - Fujitsu in Japan, descendants of AT&T Bell System in USA
- NIST work showed that \( t \)-way testing for \( t > 2 \) was needed
- In 2015 combinatorial \( t \)-way testing gaining respect
  - CT included in software engineering at leading universities
  - Lockheed Martin Corp reports savings of 20% and increased test coverage from 20% to 50%
  - Each IWCT from 2012 to 2015 received over 20 submissions
  - ACTS tools downloaded by over 2000 individuals, sharing fine
test
  - CT based on covering arrays; great advancements in generation of small size CT (Charlie Colbourn et al)
Technical challenges in CT

- Modeling test space: specify factors, values, constraints
  - Domain specific
- Generation of test suite with constraints
- Expected behavior of SUT for each test case
- Fault localization
- Integration of CT in larger test infrastructure
ACTS research tools

- Freely distributed by NIST
  - IPOG: test generation (Yu Lei et al); performs favorably for size and time to generate; IPOG-F, IOPG-D
  - CCM: combinatorial coverage measurement (Rick Kuhn et al)
  - Sequence covering array generator (Rick Kuhn et al)
  - Classification tree aid for input modeling (CMU students)
  - Access Control Policy Tester (Vincent Hu)

- BEN: CT based fault localization (Yu Lei et al)

- Lager covering arrays (Pepe Torres et al)
ACTS/IPOG

• Supports constraints, excluded invalid combinations
• Two test generation modes: scratch and extend
• Supports variable strength test suits
• Verifies that a test suite covers all t-way combinations
• User can specify expected output for each test
• Supports three interfaces: GUI, CLI, API

• Demonstration of IPOG by Professor Yu Lei
Summary

- CT is versatile approach to complement other software testing methods
- Generation of combinatorial $t$-way test suites is now practical
- Great progress on CT based fault localization
- Input modeling is application specific
  - Further advancements will require applications
- Particular interest in following areas
  - Cyber-security, Healthcare IT, Software for big data, Internet of thing
- ACTS team is excited to investigate common interests with SBA-Research; open invitation to visit NIST