Peter M. Kruse and Kiran Lakhotia

Multi Objective Algorithms for Automated Generation of Combinatorial Test Cases with the Classification Tree Method

Multi Objective Algorithms

- Algorithms in Multi Objective Problems (MOP)
  - optimize >2 conflicting constraints
  - do not usually have a single solution
  - Pareto optimal solutions
- Pareto front and Pareto optimal set

Pareto Optimal Set: For a given MOP $f(x)$, [illegible] Pareto Optimal Set $(P*)$ is defined as: $P* := \{x \in F \mid \neg\exists$ [illegible] $f(x') \leq f(x)\}$, where F is the decision variable space.

- Subset of Evolutionary Algorithms [illegible] Multi Objective Evolutionary Algorithms (MOEA) suited for MOPs
- Advantages over hill climbers or a single objective Genetic Algorithms

Two well known algorithms:

- **NSGA-II** Elitist Nondominated Sorting Genetic Algorithm
- **SPEA2** Strength Pareto Evolutionary Algorithm

No details needed on day #3 of SSBSE

Combinatorial Test Cases

Combinatorial Interaction Testing (CIT) is a black box system testing technique that samples inputs, configurations and parameters and combines them in a systematic fashion.

Creating functional tests derived from software's specifications

Thomas J. Ostrand and Marc J. Balcer. The Category-Partition Method for specifying and generating functional tests, 1988

Coverage Criterion: Minimum, Maximum, Pairwise, N-Wise

Pairwise NP Complete

Yu Lei, Kuo-Chung Tai. In-parameter-order: a test generation strategy for pairwise testing, 1998

N-wise NP Complete

Alan W. Williams and Robert L. Probert. A measure for component interaction test coverage, 2001

Constraints

Myra B. Cohen, Matthew B. Dwyer, and Jiangfan Shi. Interaction testing of highly-configurable systems in the presence of constraints, 2007

Classification Tree Method

Classification Tree Method

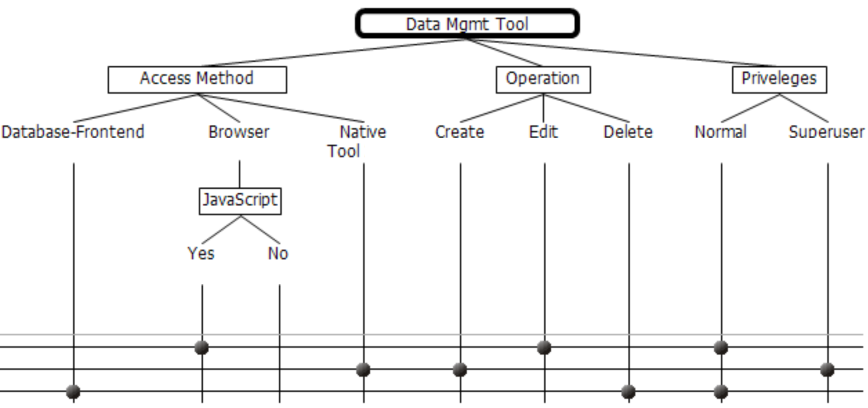
Matthias Grochtmann and Klaus Grimm. Classification trees for partition testing, 1993

Classification Tree Editor

Eckard Lehmann and Joachim Wegener. Test case design by means of the CTE XL, 2000

Prioritized Test Case Generation using CTE

Peter M. Kruse and Magdalena Luniak. Automated test case generation using classification trees, 2010



Proposal

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Use of Multi-Objective Algorithms for Automated …

- … Conventional Generation
- … Prioritized Generation
- … Test Sequence Generation

Conventional Generation

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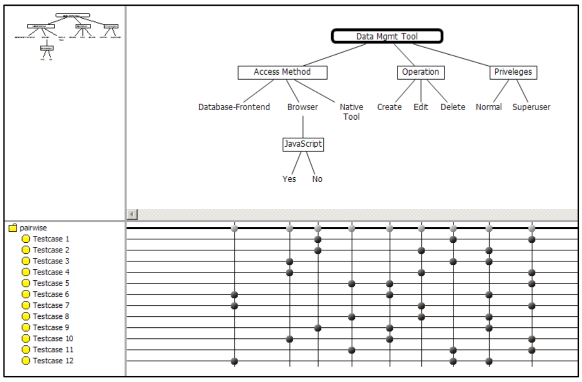
- Old CTE XL 1.x
  - Non-deterministic Approach inspired by AETG
- CTE XL Pro 2.x
  - Deterministic Approach using BDDs
- Seeding, Constraints, Mixed-Strength, Parameter Hierarchies
- Optimization Target:
  - Constraints
  - Coverage
  - Minimization of test suite size



- Benchmarks / Related work

  Yu Lei, Kuo-Chung Tai. In-parameter-order: a test generation strategy for pairwise testing, 1998

  Jazek Czerwonka. Pairwise testing in real world, practical extensions to test case generators, 2006

  James D. McCaffrey. Generation of pairwise test sets using a simulated bee colony algorithm, 2009

Conventional Generation

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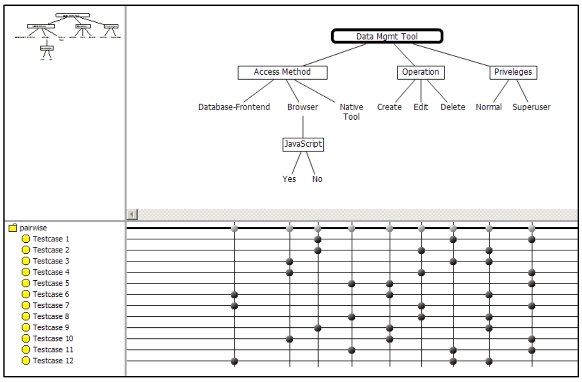

- Benchmarks / Related work

Test Space	AETG [10]	IPO [28]	TConfig [30]	CTS [17]	Jenny [18]	DDA [7]	AllPairs [1]	PICT [9]	ACTS [25]	FoCuS
3^4	9	9	9	9	11	?	9	9	12	10
3^{13}	15	17	15	15	18	18	17	18	21	20
$4^{15}3^{17}2^{29}$	41	34	40	39	38	35	34	37	33	37
$4^1 3^{39} 2^{35}$	28	26	30	29	28	27	26	27	28	30
2^{100}	10	15	14	10	16	15	14	15	16	15
10^{20}	180	212	231	210	193	201	197	210	215	259

Table 3: Comparing CTD results with known CTD algorithms on standard test spaces

Conventional Generation

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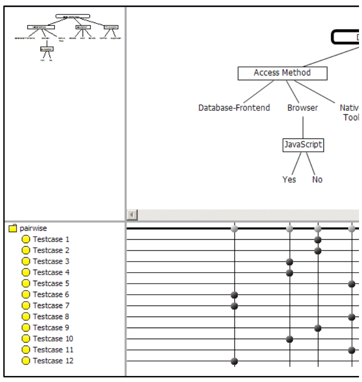


- Benchmarks / Related work

Yu Lei, Kuo-Chung Tai. In-parameter-order: a test generation strategy for pairwise testing, 1998

Jazek Czerwonka. Pairwise testing in real world, practical extensions to test case generators, 200

James D. McCaffrey. Generation of pairwise test sets using a simulated bee colony algorithm, 20

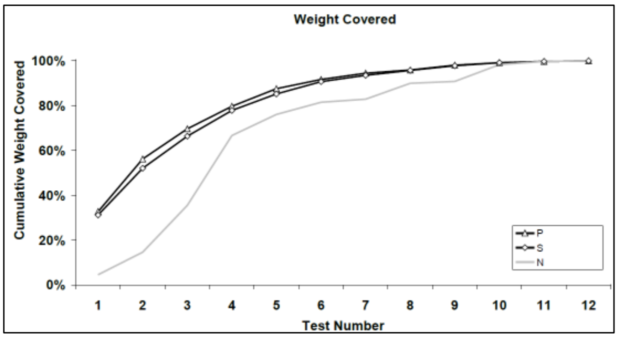
Brady J. Garvin, Myra B. Cohen, and Matthew B. Dwyer. An improved meta-heuristic search for constrained interaction testing. SSBSE, 2009

TABLE 23. Benchmark examples

Name	Model	Constraints
SPIN-S	$2^{13}4^5$	2^{13}
SPIN-V	$2^{42}3^2 4^{11}$	$2^{47}3^2$
GCC	$2^{189}3^{10}$	$2^{37}3^3$
Apache	$2^{158}3^8 4^4 5^1 6^1$	$2^3 3^1 4^2 5^1$
Bugzilla	$2^{49}3^1 4^2$	$2^4 3^1$
1	$2^{86}3^3 4^1 5^5 6^2$	$2^{20}3^3 4^1$
2	$2^{86}3^3 4^3 5^1 6^1$	$2^{19}3^3$
3	$2^{27}4^2$	$2^9 3^1$
4	$2^{51}3^4 4^2 5^1$	$2^{15}3^2$
5	$2^{155}3^7 4^3 5^5 6^4$	$2^{32}3^6 4^1$
6	$2^{73}4^3 6^1$	$2^{26}3^4$
7	$2^{29}3^1$	$2^{13}3^2$
8	$2^{109}3^2 4^2 5^3 6^3$	$2^{32}3^4 4^1$
9	$2^{57}3^1 4^1 5^1 6^1$	$2^{30}3^7$
10	$2^{130}3^6 4^5 5^2 6^4$	$2^{40}3^7$
11	$2^{84}3^4 4^2 5^2 6^4$	$2^{28}3^4$
12	$2^{136}3^4 4^3 5^1 6^3$	$2^{23}3^4$
13	$2^{124}3^4 4^1 5^2 6^2$	$2^{22}3^4$
14	$2^{81}3^5 4^3 6^3$	$2^{13}3^2$
15	$2^{50}3^4 4^1 5^2 6^1$	$2^{20}3^2$
16	$2^{81}3^3 4^2 6^1$	$2^{30}3^4$
17	$2^{128}3^3 4^2 5^1 6^3$	$2^{25}3^4$
18	$2^{127}3^2 4^4 5^6 6^2$	$2^{23}3^4 4^1$
19	$2^{172}3^9 4^9 5^3 6^4$	$2^{38}3^5$
20	$2^{138}3^4 4^5 5^4 6^7$	$2^{42}3^6$
21	$2^{76}3^3 4^2 5^1 6^3$	$2^{40}3^6$
22	$2^{72}3^4 4^1 6^2$	$2^{20}3^2$
23	$2^{25}3^1 6^1$	$2^{13}3^2$
24	$2^{110}3^2 5^3 6^4$	$2^{25}3^4$
25	$2^{118}3^6 4^2 5^2 6^6$	$2^{23}3^3 4^1$
26	$2^{87}3^1 4^3 5^4$	$2^{28}3^4$
27	$2^{55}3^2 4^2 5^1 6^2$	$2^{17}3^3$
28	$2^{167}3^{16}4^2 5^3 6^6$	$2^{31}3^6$
29	$2^{134}3^7 5^3$	$2^{19}3^3$
30	$2^{73}3^3 4^3$	$2^{31}3^4$

Prioritized Generation

- Old CTE XL 1.x
  - Not Available
- CTE XL Pro 2.x
  - Deterministic Approach, Greedy Algorithm



- Prioritization vs. Weight
- Constraints

- Optimization Target:
  - Constraints
  - Coverage
  - Prioritization of test suite (by importance of test cases)
  - Minimization of test suite size

- Benchmarks / Related work

Sebastian Elbaum, Alexey G. Malishevsky, and Gregg Rothermel. Test case prioritization: A family of empirical studies, 2002

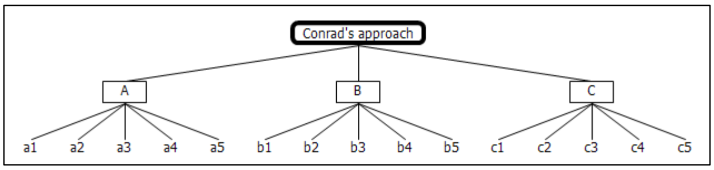
Renée C. Bryce and Charles J. Colbourn: Prioritized interaction testing for pair-wise coverage with seeding and constraints, 2006

Table 10
Sizes of biased covering arrays with different weight distributions

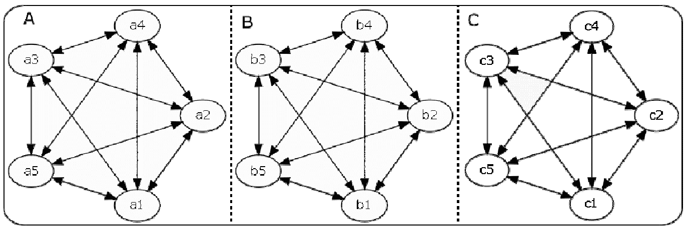
Weighting	Equal	$\frac{1}{v_{max}}^2$	$\frac{50}{50}$ Split	Random
3^4	9	13	9	13
10^{20}	206	314	225	223
3^{100}	32	38	31	32
$10^1 9^1 8^1 7^1 6^1 5^1 4^1 3^1 2^1$	94	125	98	101
$8^2 7^2 6^2 2^4$	70	98	77	81
$15^1 10^5 5^1 4$	175	238	185	188
$3^{50} 2^{50}$	28	35	28	28

Test Sequence Generation

- Old CTE XL 1.x
  - Not Available
- CTE XL Pro 2.x
  - Internal Prototype Implementation



- Constraints
  - Dynamic Constraints



- Optimization Target:
  - Constraints
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- Benchmarks / Related work

Hasan Ural. Formal methods for test sequence generation, 1992

D. Richard Kuhn, Raghu N. Kacker, and Yu Lei. Practical combinatorial testing. Technical report, 2010

Jungsup Oh, Mark Harman, Shin Yoo. Transition Coverage Testing for Simulink/Stateflow Models Using Messy Genetic Algorithms, GECCO 2011

Lefticaru et al., Windisch/Lindlar, Zhan and Clark, …

Test Sequence Generation

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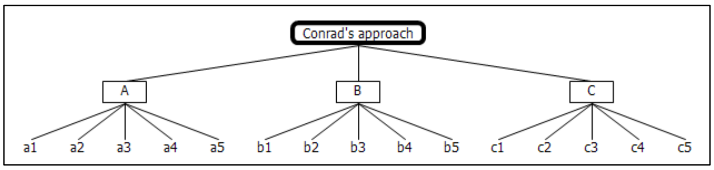

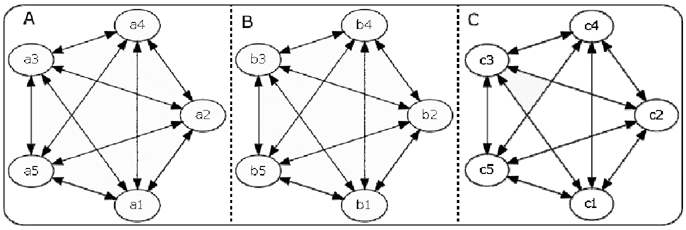

- Benchmarks / Related work

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Lefticaru et al., Windisch/Lindlar, Zhan and Clark, …

Hierarchical Concurrent Chinese Postman Problem, anyone?

Summery

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We plan to use Multi-Objective Algorithms for Automated …

- … Conventional Generation
- … Prioritized Generation
- … Test Sequence Generation

- Stay tuned for benchmark results …

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