

Contents

I. Foundations	1
1. Introduction	3
1.1. Research Motivation	3
1.2. Research Context	5
1.3. Research Objective	6
1.4. Structure of this Work	9
1.5. List of Publications	11
2. Running Example: Ordering Web Service	13
3. Conceptual Foundations	17
3.1. A Taxonomy of Dependable Programs	17
3.1.1. Dependable Programs	17
3.1.2. Combinatorial Testing	25
3.2. An Extended Taxonomy of Robust Programs	38
3.2.1. Robust Programs	38
3.2.2. Exception Handling	43
3.2.3. Combinatorial Robustness Testing	50
4. Related Work	55
4.1. Combinatorial Robustness Testing	55
4.1.1. General Contributions	56
4.1.2. CT Test Methods	58
4.1.3. CRT Test Methods	60
4.2. Non-Combinatorial Robustness Testing	69
II. A Combinatorial Robustness Test Method	71
5. A Combinatorial Robustness Fault Model	73
5.1. Fault Detection Effectiveness in the Presence of Invalid Input Masking	74
5.1.1. Motivation	74
5.1.2. Applying the t-Factor Fault Model	75
5.1.3. Experiment Design	81
5.1.4. Results and Discussion	84
5.1.5. Threats to Validity	90

5.2.	A Classification of Robustness Fault Characteristics	91
5.2.1.	Configuration-independent Robustness Faults	91
5.2.2.	Configuration-dependent Robustness Faults	94
5.3.	A Case Study on Minimal Failure-causing Schemata	97
5.3.1.	Motivation	97
5.3.2.	Case Study Design	98
5.3.3.	Results and Discussion	100
5.3.4.	Threats to Validity	104
5.4.	A Refined t-Factor Fault Model for Robustness Faults	105
6.	A Combinatorial Robustness Input Parameter Model	111
7.	Combinatorial Robustness Test Adequacy Criteria	119
7.1.	Existing t-wise Combinatorial Test Adequacy Criteria	119
7.2.	Combinatorial Test Adequacy Criteria for Strong Invalid Test Inputs	127
8.	Combinatorial Robustness Test Selection Strategies	143
8.1.	Test Selecting Strategies for Valid Test Inputs	143
8.2.	Test Selection Strategies for Strong Invalid Test Inputs	147
III.	Supporting Techniques for Combinatorial Robustness Testing	157
9.	Detection and Repair of Over-Constrained RIPMs	159
9.1.	Detection and Manual Repair of Over-Constrained RIPMs	160
9.1.1.	A Process for Detection and Manual Repair	160
9.1.2.	Identifying Missing Invalid Schemata	164
9.1.3.	Explaining Conflicting Constraints	166
9.2.	Semi-Automatic Repair of Over-Constrained RIPMs	169
9.2.1.	Automatic Diagnosis of Over-Constrained RIPMs	170
9.2.2.	Automatic Relaxation of Conflicting Constraints	174
9.2.3.	Selection and Application of Diagnosis Hitting Sets	177
9.3.	Strong Invalid Test Input Selection from Over-Constrained RIPMs	178
9.3.1.	General Idea of Soft Constraint Handling Strategies	178
9.3.2.	Basic Soft Constraint Handling Strategy	180
9.3.3.	Diagnostic Soft Constraint Handling Strategy	182
10.	Automatic Generation of Error-Constraints	187
10.1.	A Process for Automatic Generating of Error-Constraints	187
10.2.	Identifying Non-Conforming Schemata	191
10.3.	Generating New Error-Constraints	196
11.	A Framework for Automated Combinatorial Robustness Testing	199
11.1.	Orchestrated Process	199
11.2.	Framework Architecture	203

11.3. Implementation of coffee4j	205
IV. Evaluation and Conclusion	209
12. Overview of Evaluation	211
13. Evaluating Combinatorial Robustness Test Selection Strategies	215
13.1. Theoretical Evaluation	215
13.2. Experimental Evaluation	219
13.2.1. Motivation	219
13.2.2. Experiment Design	219
13.2.3. Experiment Setup	220
13.2.4. Experiment Scenarios	221
13.2.5. Results and Discussion	223
13.2.6. Threats to Validity	226
13.3. Case Study-based Evaluation	227
13.3.1. Motivation	227
13.3.2. Case Study Design	228
13.3.3. Results and Discussion	230
13.3.4. Threats to Validity	242
14. Evaluating Detection and Repair of Over-constrained RIPMs	245
14.1. Evaluating the Detection and Manual Repair of Over-Constrained RIPMs	245
14.1.1. Experiment Design and Setup	245
14.1.2. Results and Discussion	246
14.1.3. Threats to Validity	248
14.2. Evaluating Semi-Automatic Repair of Over-Constrained RIPMs	249
14.2.1. Experiment Design and Setup	249
14.2.2. Results and Discussion	249
14.2.3. Threats to Validity	251
14.3. Evaluating Strong Invalid Test Input Selection from Over-Constrained RIPMs	253
14.3.1. Experiment Design and Setup	253
14.3.2. Results and Discussion	254
14.3.3. Threats to Validity	258
15. Evaluating Automatic Generation of Error-Constraints	259
15.1. Experiment Design and Setup	259
15.1.1. Fault Characterization Algorithms	260
15.1.2. Scenarios	260
15.1.3. Experiments	261
15.1.4. Data Collection Procedure	262
15.2. Results and Discussion	263
15.2.1. Experiment 1	263

15.2.2. Experiment 2	264
15.2.3. Experiment 3	265
15.2.4. Experiment 4	265
15.2.5. Summary	267
15.3. Threats to Validity	269
16. Conclusion	271
16.1. Summary	271
16.2. Future Work	274
V. Appendix	277
A. Data of FDE in the Presence of Invalid Input Masking	279
B. Data of Evaluating Combinatorial Robustness Test Selection Strategies	335
C. Data of Evaluating Semi-Automatic Repair of Over-Constrained RIPMs	341
D. Data of Evaluating Automatic Generation of Error-Constraints	345
Abbreviations	351
Symbols and Functions	353
Glossary	357
List of Figures	365
List of Listings	367
List of Tables	369
Supervised Bachelor and Master Theses	375
Bibliography	377