

# Contents

<b>Abstract</b>	<b>v</b>
<b>Resumen</b>	<b>vii</b>
<b>Resum</b>	<b>ix</b>
<b>I Introduction</b>	<b>1</b>
<b>1 Preamble</b>	<b>3</b>
1.1 Motivation . . . . .	3
1.2 Analysis Techniques . . . . .	5
1.3 Contributions and Main Goals . . . . .	10
1.4 Structure of this thesis . . . . .	13
<b>II Program Slicing</b>	<b>17</b>
<b>2 Preliminary Definitions and Notation</b>	<b>19</b>
2.1 Program Slicing with System Dependence Graphs . . . . .	22
2.2 Program Slicing Algorithm . . . . .	24
2.3 Program Slicing of Object-Oriented Programs . . . . .	26
2.4 Language-Independent Program Slicing: Observation-Based Slicing . . . . .	29
<b>3 Flow Dependence for Java Object-Oriented Programs</b>	<b>31</b>
3.1 Limitations of the JSysDG . . . . .	31
3.2 A novel definition of flow dependence . . . . .	33
3.3 Implementation . . . . .	47
3.4 Experimental Results . . . . .	50
3.5 Related Work . . . . .	53
<b>4 Field-Sensitive Slicing with Constrained Graphs</b>	<b>57</b>
4.1 The CE-PDG . . . . .	59
4.2 Dealing with recursive data structures . . . . .	62
4.3 Slicing the CE-PDG . . . . .	63
4.4 The CE-SDG . . . . .	79
4.4.1 Summary edges and grammar productions . . . . .	80
4.4.2 Summary constraints for unknown source code functions	84
4.4.3 Dealing with recursion . . . . .	85
4.4.4 Slicing the CE-SDG . . . . .	86

4.5	Implementation . . . . .	88
4.6	Experimental Results . . . . .	88
4.7	Related Work . . . . .	92
<b>5</b>	<b>Overcoming SDG Limits: The Expression Dependence Graph</b>	<b>95</b>
5.1	Representation problems of the SDG . . . . .	95
5.2	From ASTs to EDGs . . . . .	100
5.3	Slicing the EDG . . . . .	113
5.4	Solving SDG limitations . . . . .	113
5.5	Implementation . . . . .	117
5.6	Empirical evaluation . . . . .	119
5.7	Related Work . . . . .	122
<b>6</b>	<b>Quasi-Minimal Slicing to Compare Program Slicers</b>	<b>125</b>
6.1	Using ASTs to Improve Granularity . . . . .	127
6.2	A Method to Produce Quasi-Minimal Slices . . . . .	128
6.2.1	Phase 1: Combining static program slicers . . . . .	128
6.2.2	Phase 2: Increasing precision via an AST-adapted ORBS algorithm . . . . .	130
6.3	Implementation . . . . .	134
6.3.1	Phase 1: <i>Slicerl</i> and <i>e-Knife</i> . . . . .	134
6.3.2	Phase 2: CutEr, Cover, and SecEr . . . . .	134
6.4	Experimental Evaluation and Results . . . . .	136
6.4.1	Phase 1: Behaviour of Slicerl and e-Knife . . . . .	136
6.4.2	Phase 2: Behaviour of ORBS and CutEr . . . . .	136
6.4.3	Empirical evaluation . . . . .	138
6.4.4	A suite of minimal slices . . . . .	141
6.5	Related Work . . . . .	143
<b>III</b>	<b>Testing &amp; Verification</b>	<b>145</b>
<b>7</b>	<b>Preliminary Definitions and Notation</b>	<b>147</b>
7.1	Analysis tools for Erlang . . . . .	147
7.1.1	Type inference in Erlang: TypEr . . . . .	147
7.1.2	Property-based testing in Erlang: PropEr . . . . .	148
7.1.3	Concolic testing in Erlang: CutEr . . . . .	148
7.2	Design by contract . . . . .	149
<b>8</b>	<b>Software Evolution Control in Erlang</b>	<b>151</b>
8.1	A novel approach to Automatic Regression Testing: Point of Interest Testing . . . . .	153
8.2	Traced information in POI testing . . . . .	155
8.2.1	Possible POI testing configurations . . . . .	157
8.3	POI testing adapted to Erlang . . . . .	159
8.3.1	Initial ITC generation . . . . .	159
8.3.2	Recording the traces of the point of interest . . . . .	161
8.3.3	Extraction of additional trace information . . . . .	166

8.3.4	Test case generation using ITC mutation . . . . .	170
8.4	POI testing with multiple POIs . . . . .	171
8.4.1	Code transformation with multiple POIs . . . . .	172
8.4.2	Differences in trace equality . . . . .	172
8.5	POI testing in concurrent environments . . . . .	175
8.6	Implementation . . . . .	175
8.7	Experimental Evaluation . . . . .	178
8.8	Related Work . . . . .	180
<b>9</b>	<b>Design-by-contract verification in Erlang</b>	<b>185</b>
9.1	Contracts in Erlang . . . . .	186
9.1.1	Contracts for sequential Erlang . . . . .	186
9.1.2	Contracts for concurrent Erlang . . . . .	192
9.2	Implementation . . . . .	198
9.2.1	Architecture . . . . .	198
9.2.2	Instrumentation . . . . .	200
9.3	Related Work . . . . .	202
<b>IV</b>	<b>Developed Tools</b>	<b>205</b>
<b>10</b>	<b>Developed Tools and User Guides</b>	<b>207</b>
10.1	JavaSlicer . . . . .	207
10.1.1	Installation and first steps . . . . .	207
10.1.2	Use case . . . . .	210
10.2	e-Knife (a CE-EDG Slicer for Erlang) . . . . .	211
10.2.1	Installation and first steps . . . . .	212
10.2.2	Use case . . . . .	214
10.3	SecEr . . . . .	216
10.3.1	Installation and first steps . . . . .	216
10.3.2	Use cases . . . . .	223
10.4	EDBC . . . . .	231
10.4.1	Installation and first steps . . . . .	232
10.4.2	Use cases . . . . .	235
<b>V</b>	<b>Conclusions and Future Research</b>	<b>239</b>
<b>11</b>	<b>Conclusions</b>	<b>241</b>
<b>12</b>	<b>Future Lines of Research</b>	<b>247</b>
12.1	Program Slicing . . . . .	247
12.2	Testing and Verification . . . . .	249
<b>Bibliography</b>		<b>251</b>